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ORIGINAL ARTICLES.

I.—The Origin of the Nile Valley in Egypt.

By W. F. Hume, D.Sc., F.R.S.E., A.R.S.M., F.G.S., Director of the Geological Survey of Egypt.

THE article which appeared by Dr. Ball in the February number of the Geological Magazine (pp. 71–6), strongly urging the origin of the Egyptian Nile Valley as due to erosion rather than faulting, is the first public expression of a widespread feeling that the familiar rift theory is based on comparatively feeble foundations, and either requires strengthening or withdrawal. It must be remembered that when the Geological Survey of Egypt commenced its operations in 1896 the relation of deep African depressions to rifts was an accepted theory which had been found applicable in a number of striking instances. As one who has studied portions of the Nile Valley and the neighbouring deserts of Egypt for some years, I submit these few remarks, adopting a somewhat more personal point of view than is usual in papers of this nature, not from a desire for controversy, but because the subject is one worthy of discussion.

During 1896 I was in frequent correspondence with Mr. Barron regarding Egyptian geology, and from his letters it was evident that two points had impressed him, viz. the absence of sand-deposits in the Eastern Desert and the abundant evidence of faulting. The widespread nature of these fractures seemed to me open to some doubt, but the first year's work in the Eastern Desert (1897–8) led me in the main to adopt Mr. Barron's views. The magnificent dislocations in the hills opposite Qena, and gigantic slip-faulting of Arras and Abu Had, north-east of that town, were too apparent to escape even superficial observation, and the discovery of the faulted areas described by Fraas, Barron, and myself near Qosseir, helped materially to strengthen the view that faults played an important part in the structure of the country.

The investigations of 1898–9 in Sinai only tended to enhance their significance, and in a paper on the "Rift Valleys of Eastern Sinai" I pointed out that a series of parallel valleys with the younger strata faulted between the older formations could only be explained as due to fractures arranged on some systematic basis. An attempt was also made to widen this conception so as to embrace the Gulf of Suez, Nile Valley, etc.

Thus far the evidence showed that disturbances of a tectonic nature were widespread in Egypt, that they had given rise to important surface features, but at the same time the rift or trough-fault view for the Nile Valley was not gaining the required basis of fact to make its position impregnable. The highly tilted gravel ridges south of Helwan, the long ridge of Gebelain in Southern Egypt, bringing up steeply dipping Cretaceous beds, the great slip-faults of the Qena–Luxor district could be invoked, but all these manifestations of earth-movement do not fit into a regular plan of trough-faulting, and for some years my colleagues and myself had, if I mistake not, abandoned (if we ever had them) any pronounced view as to the form of the Nile Valley near Cairo being directly influenced by faults. At the same time the great differences of structure between the two sides of the Nile both near Cairo and in the Qena–Luxor reach seemed to demand some explanation, which might be of wider character than mere erosion.

Till 1900 I may frankly say that all my studies in the outer deserts of Egypt had biassed me in favour of a fault origin for the major portion of the Nile Valley; from that period onward the tide of thought took pause. Many visits to Nubia showed that faults were of minor importance there, while a study between Esna and Aswan, which was carried out on foot, every point of any interest within reasonable distance of the river being examined, further strengthened the view that in this reach of the river longitudinal faults were of no significance. On the contrary, transverse faults, such as the one at Kom Ombo, produce the most striking effects. The difference between the high Nubian Sandstone cliffs and hills on the right bank near Edfu, etc., and the comparatively low gravel ridges on the left or west bank, led to the view that the river was eroded along the original outcrop of the softer Cretaceous strata, to whose line of strike the present stream is roughly parallel. In 1906 satisfactory evidence was obtained of a transverse anticlinal roll in the hills south-east of Qena, a roll which in large measure explains the abrupt bend of the river at this point, along the outcrop of these Cretaceous beds.

This does not, however, satisfy the problem to the full; we have still to explain the remarkable ravine of the Nile between Sohag and Assiut, and the north-westward bend near Cairo. For the latter feature it seems reasonable to suggest that the river has in the main taken advantage of the more easily denuded Upper Moqattam Beds, the geology of the two banks between Cairo and the Fayum differing geologically in marked respects. As regards the straight-lined ravine of the Nile, it is of interest to note that its long axis corresponds with a synclinal arrangement of the strata, which is also the cause of the marked differences between the two sides of the Nile south of Qena. As I hope a general geological map of Egypt on a scale of 1 : 1,000,000 will appear in the course of the late summer, there will be an opportunity for all interested in the subject to weigh the evidence and form their own opinions.

The direction, therefore, in which my own views tend at the present time are put dogmatically. The southern portion of the

Egyptian Nile from Aswan to beyond Qena owes its origin to denudation of the softer Cretaceous beds, as already suggested in the *Cairo Scientific Journal*. This view is, I believe, shared by Mr. Beadnell. Owing to the temporary dominance of a transverse roll near Qena the river has turned, following the direction of outcrop of these softer strata until its further course north-westward was determined by a well-marked syncline. North of Assiut a second fold may have determined the northward deflection of the Nile, the river breaking through where the Nubian Sandstone may have had an outcrop north of the Pyramids near Abu Roash. This conception is not so imaginative as might at first sight appear, there being an exposure of Nubian Sandstone in the Abu Roash Hills close to the river-valley.[1] The slipping of heavy masses of Eocene limestone on Cretaceous shales has exaggerated the fold effects in the region between Luxor, the slip-faults being often on a gigantic scale, but these presumably cannot be regarded as evidence in favour of true trough-faulting.

So far as the Nile is concerned, therefore, I hold that folding plus erosion plus slip-faulting is sufficient to account for all the phenomena observed, a view still further emphasized by a recent visit to the desert plateau immediately north of the Qena depression. Here it is possible to study valleys in every stage of formation. The country is remarkably folded, though the individual dips seldom exceed 10°, and it is possible within a very short area to find evidence of the most varying causes of erosion. At the head of Wadi Gurdi the valley has obviously been formed along a cracked anticline; elsewhere synclinal folds have been responsible for the principal drainage-lines, whilst multiple small folds, like the waves of the sea, have determined many of the twists and turns. In addition to this complex folding, which was entirely unexpected, the rocks themselves are of a nature which specially lends itself to erosion by water. The lower part of the Eocene Series in this region is a white chalk, showing evidence of intense current-action. In these strata, caves, honeycombing of the limestone, natural bridges, and cylindrical channels, cut through the solid rock, testify to the intense activity of the erosive forces; while the deep ravines, which seam every part of this desert area, vie with the Nile Valley itself in the height of their bounding cliff-walls and the steepness of their sides. If it be remembered that the Nile Valley ravine is in its southern portion cut through these easily denuded materials, the conception of the erosion of the Nile Valley is not one which involves too great a tax on our imagination.

When, however, we consider the origin of the Gulf of Suez, I must confess that I am not prepared to go so far as my friend and colleague Dr. Ball is prepared to do. Let us grant fully the broken anticline character of the Wadi Araba area; but what does that very admission involve? Why do the Miocene beds which are found north of the northern limb of this broken anticline (the North Galala Hills) pass across into Sinai, and only reappear again in the Eastern Desert of Egypt to the south of the southern limb of

[1] See Mr. Beadnell's map of Abu Roash.

the Araba anticline, while no Miocene strata have been found in the Araba depression itself? The evidence, as I read it, points to this region having been a domed area during Miocene times, and I can conceive of no erosive agent which would break across this great earth-feature without the intervention of fracture. Be it remembered, too, that the regularity of the parallel ranges (Gebels Esh, Zeit, etc.) further south is geologically more apparent than real. In the Esh range, as I pointed out in the Eastern Desert Memoir of 1897, on the westward flank of the hills, the strata follow one another in proper succession, dipping westward as the one-half of a regular anticline. To the east of its central cone of igneous rocks what appears? Except towards the northern end of the range none of these well-developed strata (from Nubian Sandstone to and including the Lower Eocene) are anywhere present, in their place being a high-tilted Miocene coral-reef. Surely such an inequality as this cannot be lightly passed over, and until good proofs to the contrary are submitted to me I consider that faulting and faulting alone can explain the phenomena.

In Sinai the intensity of the faulting is so obvious that I await wider confirmation of its extent with equanimity, believing that the excellent effort made by Mr. Barron to unravel this most difficult problem will remain a permanent monument to his zeal and his industry. Very few would have done as much, or even a tithe as much, in the time at his disposal, and under the physical conditions which he was called upon to face. Only those who know something of the bitter cold of a Sinai winter, or the blinding sandstorms of the country between Suez and Tor, can appreciate his labours at their true value, and will be able to treat in a lenient spirit any errors of detail that may be revealed by subsequent close research in connexion with developing industries. As regards the eastern portion of Sinai, I have not one word to withdraw from the account of the rifts given in my memoir on that region, considering that the trough-fault view is the only explanation which satisfies all the conditions, geological and physical, presented by the parallel valleys of that complicated mountainous region.

The conception which seems best to satisfy all the conditions of Egyptian geology appears to involve a major north and north-westward folding which in the oases, though marked, and in the first instance originating those depressions, has nevertheless only produced fracture effects to a minor extent. (This statement is necessarily relative, for those who have read Mr. Beadnell's "An Egyptian Oasis" will remember the important fracture-line determining the line of wells in Kharga Oasis.)

In the Nile Valley *erosion* seems to have been the principal factor, the river either following the outcrops of the softer strata or the synclinal portions of the fold. The many fault-systems bordering it, especially on the east (Cairo–Suez region, Helwan area, Qena–Luxor slip-fault district, Kom Ombo plain), are not in direct relationship to the present course of the river, or in the case of the great slip-faults only appear to be so, the limestones in the cliffs bordering the Nile slipping on and crushing the Cretaceous shales underlying them.

For the Gulf of Suez, it seems difficult to explain the present conditions of its cutting through a gigantic dome, taken together with the inequilateral structure of the parallel ranges bordering the gulf, without invoking the aid of very serious fractures, whose activities are marked in most pronounced fashion on the peninsula of Sinai. Thus we have an earth wave-system gathering strength as it passes from east to west, the great trough being Egypt itself with its river in part marking the basin centre, while the wave-crest reveals itself in the serrated peaks and barren hills of the Eastern Desert and the wilderness of Sinai. Necessarily, as with the waves of the sea, this great system is broken into minor crests and hollows, domes rather than anticlines will be the rule, while curved fault-systems will surround them. All these features will no doubt become more and more marked as the detailed geological structure demands attention from economic or other reasons. In Sinai the north-west trend of the waves is replaced by a dominant north-eastward direction, but we know far too little of Northern Arabia to dogmatize as to its meaning and significance. A second, or transverse system of folds, is no doubt of great importance, and its true meaning will become more obvious as study proceeds, but as this involves work in regions difficult of access, or complicated in outline, progress will necessarily be slow, nor do these earth-movements bear prominently on the question.

Briefly summarizing the point of view I at present hold—

1. The main structure of Egypt is determined by two major fold-systems, one having dominant north or north-west trend, the other more or less transverse to this system.

2. In the north-trending fold-system the wave-crests and troughs become more pronounced from west to east, finally resulting in fractures of the greatest geographical importance.

3. In the depression containing the oases, comparatively gentle folding has resulted in the denudation of those portions where the anticlinal structure is most pronounced, fracture being unimportant as regards surface-features, though in Kharga of great moment for water-supply.

4. The Nile Valley is regarded as due in the main to the combination of the north-trending fold, erosion of the softer Cretaceous strata in the south of Egypt, and the less resistant members of the Middle Eocene in Northern Egypt, the connecting Nile ravine following the axial line of the centre of the synclinal trough.

5. The Gulf of Suez, though in direction determined by the dominant fold-trend, has required fracture for its full formation, there being possibly a minor fold region due to such fracturing between the Red Sea Hills and the main range of Sinai.

6. In Sinai itself the fold-trend swings from north-west to north-eastward, and fracture-lines almost completely mask the original folds, which are only indicated by the trends of the gulfs and their parallel valleys.

II.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(Plate XXX.)

(*Continued from the June Number*, p. 260.)

Rhagasostoma Novaki, nom. nov.

Syn. *Membranipora depressa*, Novak, Denkschr. d. kais. Ak. d. Wiss. zu Wien, Math.-Naturw. Cl., Bd. xxxvii, p. 88, Taf. ii, figs. 9, 10.

Novak considered this form within the range of variation of *Cellepora depressa*, Hag., but Canu[1] recognizes it as a *Rhagasostoma*. It appears to be so closely related to a very distinct and persistent form which is very abundant and characteristic at Trimingham that I do not like to treat them as anything but two forms of a single hitherto unnamed species, and the form admirably figured by Novak must of course be the type of the species.

Rhagasostoma Novaki, mihi, var. Anglica, nov. Pl. XXX, Fig. 1.

This is the above-mentioned form from Trimingham. It is distinguished from Novak's type by the squareness of the aperture, the much greater depth of the sinuses, and the general prevalence of a distinct inflexion of the sides of the aperture which makes the sinuses slightly bottle-shaped. The avicularia often show an interesting structure which would no doubt be found also in perfect specimens of Novak's form; the sinus at the lower end of the aperture is closed by a narrow rectangular projection into the aperture just wide enough to seal up the sinus, and which is so deep-set as to appear to be not so much a process of the edge of the front wall as attached to its under surface.

Very abundant at Trimingham; one specimen in zone of *B. mucronata*, Isle of Wight.

Cribrilina claviceps, nov. Pl. XXX, Figs. 2–5.

Zoarium always adherent.

Zoœcia very variable in size, length ·68–·9 mm., breadth ·35–·5 mm.; aperture variable in length and breadth, shaped like a keyhole, with a thickened margin round the upper part; what appear to be calcareous opercula may be sometimes seen inside the zoœcia or even (Fig. 4) in situ; a pair of perforate tubercles often possessing a slight beak occur very regularly beside the aperture, and others occur somewhat irregularly on the edges of the front wall; front wall slightly but decidedly keeled (Fig. 4), and showing six or seven pairs of faint radiating imperforate furrows.

Oœcia not observed.

Avicularia not observed except so far as the tubercles may be avicularian.

Occurs regularly but sparingly in the *M. cor-anguinum* zone at Gravesend and in Hants, and in the *Marsupites* zone in Hants.

[1] Bull. Soc. Géol. France, 1900, p. 428.

CRIBRILINA FURCIFERA, nov. Pl. XXX, Figs. 6–8.

Zoarium always adherent.

Zoœcia very variable in size, length ·5–·7 mm., breadth ·4–·58 mm.; aperture semicircular, with a stout perforated tubercle on either side, and generally two, sometimes three, and rarely four more slender perforated tubercles between them round the upper lip; the lower lip is much thickened, especially down the centre of the zoœcium; its upper edge is primarily straight, but frequently develops a stout forked projection, the arms of which reach to a point where they partly overhang and appear to rest on, but do not in fact touch, the stout paired tubercles; at other times it develops a blunt denticle only; front wall generally highly arched, but varies down to almost flat as in Fig. 8, and covered with radiating ribs varying from very fine and numerous as in Fig. 6, to stout and few as in Fig. 8, the normal type with fairly fine and numerous ribs, only clearly distinguishable round the margins, being represented by Fig. 7; the furrows between the ribs are only perforated once, at their outer extremity. The side walls of those zoœcia in which alone they are visible, i.e. those at the edge of the zoarium, are rather splayed and have large foramina in them, one of which, at the extreme upper end of the zoœcium, is quite invariable in its occurrence.

Oœcia very large in proportion to the zoœcium, of the globose type, but with a tendency to become slightly pointed, and with a strongly recurved free edge; they arise just above the pair of stout tubercles, but envelop the others.

Avicularia. Small, depressed, slightly conical cells of irregular outline, with a sub-central rounded aperture and one or two large foramina in the front wall, such as may be seen in Fig. 8, occur sparingly but persistently, and may be in the nature of vicarious avicularia.

This species is not uncommon in the *M. cor-anguinum* and *Marsupites* zones of Kent and Hants, is common in the *Act. quadratus* zone of Hants and Sussex, and occurs also in the *B. mucronata* zone of Hants.

CRIBRILINA FILLIOZATI, nov. Pl. XXX, Figs. 9 and 10.

Zoarium always adherent, resembling that of *C. furcifera*.

Zoœcia small, length ·58–·72 mm., breadth ·4–·5 mm.; aperture circular, but with the lower one-fourth of its circumference cut very sharply back so as to include an arc of a slightly larger circle; front wall gently arched, almost smooth, the radiating ribs and furrows which fix the generic position being almost obliterated; the outside zoœcia show very regularly a large foramen almost at the head on the sloping surface above the aperture.

Oœcia very large, strongly resembling those of *C. furcifera*, but relatively rather longer and narrower, and with a stronger tendency to be pointed.

Avicularia not observed.

Occurs sparingly in the *Act. quadratus* zone in Hants.

It will be observed that the last three species are none of them typical *Cribrilinæ*, and in two of them the furrows are wholly

imperforate. At the same time their front walls are obviously of Cribrilinid type, i.e. built up from marginal spines more or less fused together, and it seems to me, as indicated at p. 292 of the volume of this Magazine for 1906, that in the Chalk it is not feasible to maintain one particular stage in the lateral fusion of spines as a separate genus *Cribrilina*, and that that genus must be enlarged to comprise all stages of lateral fusion short of total obliteration of the spinous origin. The only alternative would be to create a new genus for all stages of lateral fusion except *Cribrilina*, as usually defined; such a genus would not admit of a positive definition, and is obviously undesirable.

EXPLANATION OF PLATE XXX.

FIG. 1. *Rhagasostoma Novaki*, var. *Anglica*. Trimingham. × 12 diam.
,, 2. *Cribrilina clavicepS*. Gravesend, Kent. × 12 diam.
,, 3. Ditto, the same specimen. × 21 diam.
,, 4. Ditto. Whitchurch, Hants. × 12 diam.
,, 5. Ditto. Gravesend. × 12 diam.
,, 6. *Cribrilina furcifera*. Andover, Hants. × 12 diam.
,, 7. Ditto. Bramford, Suffolk. × 12 diam.
,, 8. Ditto. Kingsgate, Kent. × 12 diam.
,, 9. *Cribrilina Filliozati*. Andover, Hants. × 12 diam.
,, 10. Ditto. West Tytherley, Hants. × 21 diam.

(*To be continued.*)

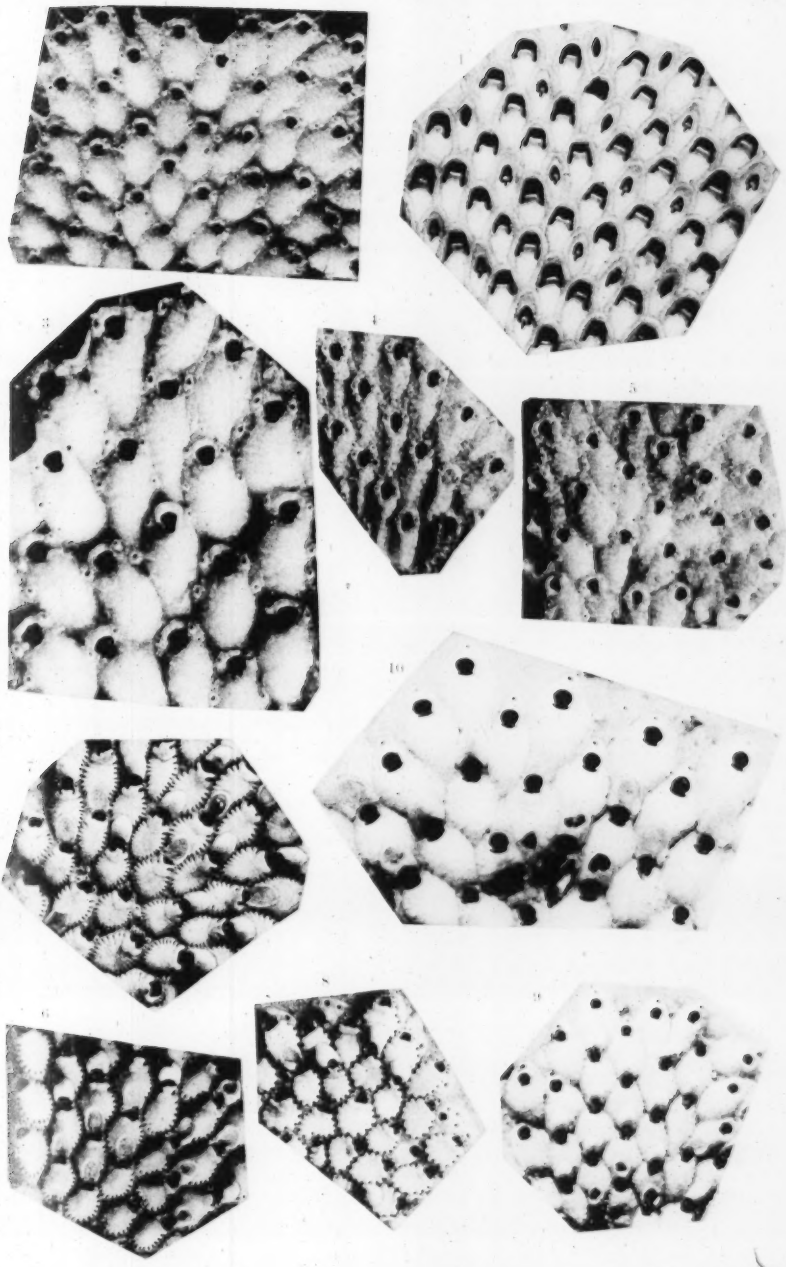
III.—The Fissure Theory of Volcanoes.

By Professor E. H. L. Schwarz, A.R.C.S., F.G.S., Rhodes University College, Grahamstown.

DR. HANS RECK has adduced an example of a volcano which, according to him, has been formed independently of a fissure. The volcano pierces the centre of a faulted block, the Herdubreid, in Iceland, and on the vertical fault-faces there is no sign of any fissure.[1] The example is probably unique in the world, and seems at first sight to negative the hypothesis that the escape of gases which tear through the earth's crust and form the chimneys of volcanoes is in the first place initiated by a fracture; on closer examination, however, the fact that the volcano stands in close relation to the faults which bound the horst, and the many cases which are known to occur where a fracture in the earth's crust may be healed at the surface so that the rocks about the fracture are subsequently more resistant than before, seem to point to the Herdubreid volcano being a normal fissure-formed volcano, only that it stands in the same relation to the fracture as a parasitic cone stands to the central crater. In other words, the chimney is an escape vent leading below the surface to one of the bounding faults of the horst.

The Herdubreid is a part of the north and south range of mountains made of palagonite tuff, which sinks towards the north below the level of the Odadahraun lava plateau, some 600 metres above sea-level, and on the south rises to 1077 metres. The Herdubreid is 1200 metres high, and is separated from the main range by a gorge,

[1] Hans Reck, "Ein Beitrag zur Spaltentrage der Vulkane": Centralblatt für Min., Geol., u. Palaeont., 1910, No. 6, p. 166.



Chalk Polyzoa.

500 metres wide; its walls are vertical, but the lower parts are hidden by debris. The square summit rises gradually to the crater, with its lavas of much more recent date than the palagonite tuff. The substructure of the volcano is shown in the four bounding fault-faces to a height of 700–800 metres above the accumulations of debris. On the north side there is a horizontal line where a darker and lighter material in the tuff meet; the whole length of the line is exposed, and there is no trace of a dislocation. The material forming the basement of the horst is quite fresh on the exposed side, since the outer surface is rapidly weathering under the influence of frost, and the weathered material is removed by wind; this applies to all the four sides of the block, so that from all sides the evidence of the want of a fissure is perfectly clear. Dr. Reck concludes his article with the statement—It is therefore proved from observation that in one case at least a fissure does not extend under the basement of a volcano for a depth of from 300 to 400 metres.

One of the best examples I know where a fracture in the earth's crust has been healed is in the Berg River Hoek, near Paal in Cape Colony. I was called in to report on the nature of the valley with regard to its being suitable for a large reservoir. The site of the proposed retaining wall was traversed by a great fracture, on either side of which the rock, quartzite belonging to the Table Mountain Series, had been brecciated for 3 or 4 yards. I investigated the fracture very fully and found that the crush-breccia, through cementation by secondary silica, had not only become very much more compact than the quartzite itself, but that the uncrushed rock beyond the crush-breccia had been also hardened by the deposition of secondary silica. The whole zone in the neighbourhood of the fracture was eminently suitable for the foundation of a retaining wall; not only so, but the cementing of the neighbouring rock showed that subsequent movement would not take place along the old fracture, but would have to find relief some distance away.

Dr. Reck admits that all the volcanic fissures of the North of Iceland lie in a north and south direction, parallel to two of the bounding faults of the Herdubreid horst, so that it is at least admissible to those who believe in the fissure theory of the origin of volcanoes to consider the Herdubreid chimney to be an offshoot of a volcanic fissure, the surface end of which has been closed by cementation.

Daubrée's experiments on the exploding of dynamite in steel shells shows us how a fissure may allow the escape of gases, and that these in tearing their way to the surface may drill cylindrical holes; the minute fracture in the case of the shells need not have extended to the surface. I have in mind, however, what I have termed a fossil earthquake, where a spherical mass of dolerite has been shot off from a horizontal sheet of that rock and has drilled a hole vertically through the overlying shale for a height of 15 feet. The example is at Cradock in Cape Colony. The cause for the ejection was probably that the molten rock encountered a reservoir of water, and in the explosion which followed a portion of the dolerite was projected upwards. The space where the projected mass of rock once was, and the path of the projectile, are filled with crushed-up shale. I call it

a fossil earthquake because the jar the explosion must have given to the earth's crust must have produced a quite appreciable earthquake at the time of its occurrence, but in the present instance it is interesting as an example where a perfectly circular vent may be drilled through the rocks by means of the eruption of volcanic material without a fracture, but this only occurs where the molten rocks come sufficiently near the surface of the earth's crust to allow the explosion of gases. The Cradock fossil earthquake is in direct connexion with a fissure filled with dolerite which was once molten, so it seems to me probable that the Herdubreid volcano likewise is connected with a volcanic fissure rather than that it should have pierced the whole thickness of the solid earth's crust down to where some reservoir of molten material might have existed.

IV.—On the Formation of Dreikante in Desert Regions.

By A. Wade, B.Sc., A.R.C.S., F.G.S.

(PLATES XXXI AND XXXII.)

WHEN one considers the part Britons have played in exploring and investigating the various desert regions of the world, one is surprised at the relatively small amount of literature that there is in the English language dealing with the phenomena which are peculiar to desert conditions. Many hazy, and even erroneous, ideas are still held with regard to the processes at work and the effects produced by the various agents of denudation.

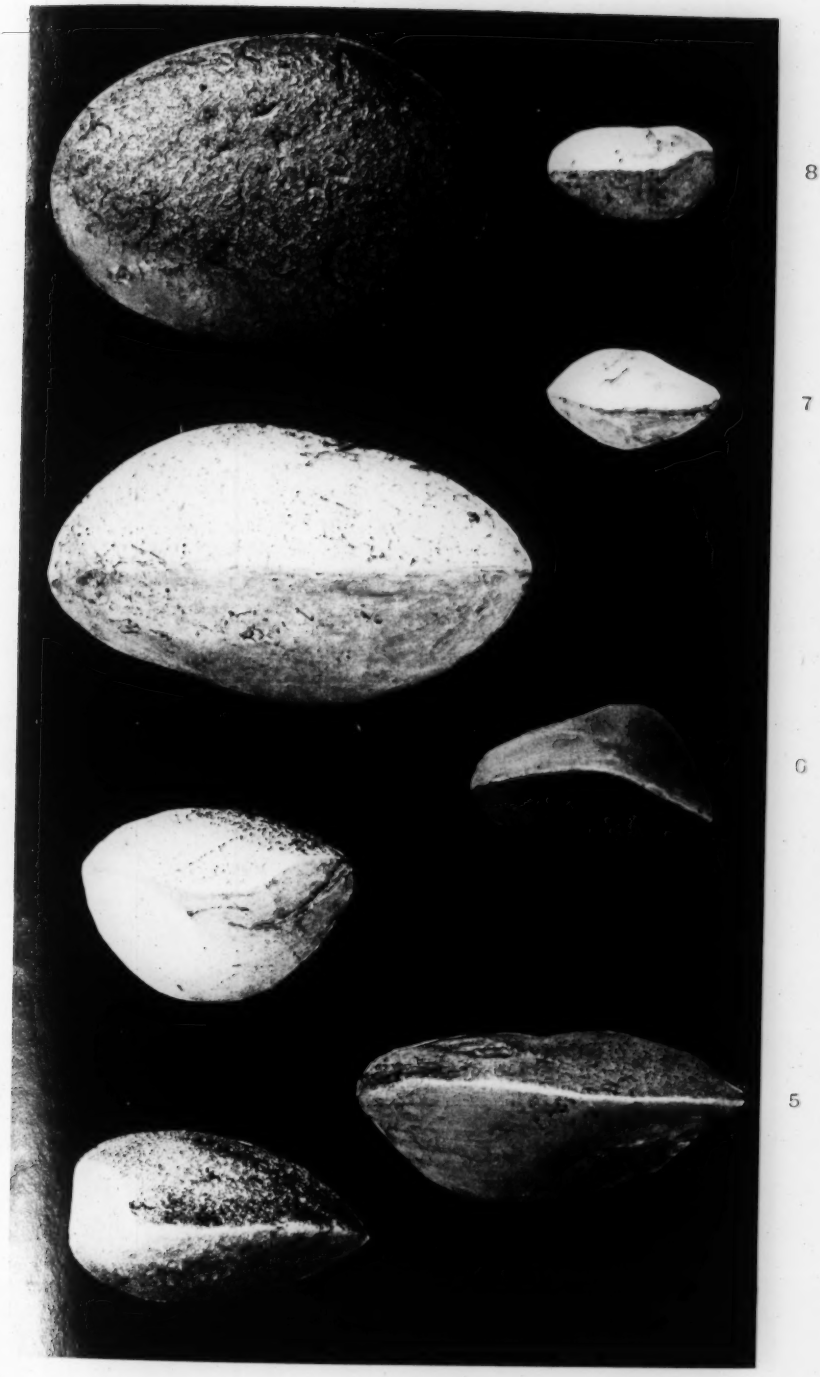
The three-edged stones known as 'dreikante', which are so characteristic and abundant in most desert regions, have been subjected to little careful investigation whilst in actual process of formation, and many ideas which appear to be incorrect are current with regard to their mode of origin.

Originally it was thought that they had been cut by river action, or by the movements of sand in the beds of rivers. Steenstrup proved that this was impossible,[1] and it is now known that they are essentially the products of wind-blown sand. In shape they usually resemble very closely a Brazil nut, and it is commonly thought that this characteristic form is produced as follows.

Fig. 1.

The travelling sand-grains strike a stone or a pebble lying on the desert. They are in consequence divided into two streams which pass along the sides of the object, wearing away the sides and producing a pointed snout to the pebble and a sharp ridge along the crest. (See Text-fig. 1.) It is difficult to see, however, why the ridge should remain equally sharp from front to back, and why the end

[1] *Geol. Fören. Stockholm*, x, p. 485 ; xiv, p. 493.



...from the Eastern Desert of Egypt, showing the gradual evolution of the ...kante" by the abrasive action of wind-blown sand from the earlier stages to

opposite to the point from which the wind usually comes should be just as pointed as the other. It is inconceivable that the deflected currents of sand-grains would keep so closely to the pebble from end to end. One would expect a pointed front and a more or less unworn end. This, however, does not occur. It seems therefore that this explanation is not quite satisfactory in its nature.

During 1909 I spent a good many months on the Eastern Desert of Egypt, and it occurred to me to make a careful examination of the dreikante, which are so abundant in the stony desert tract which stretches between the Red Sea Hills and the coast.

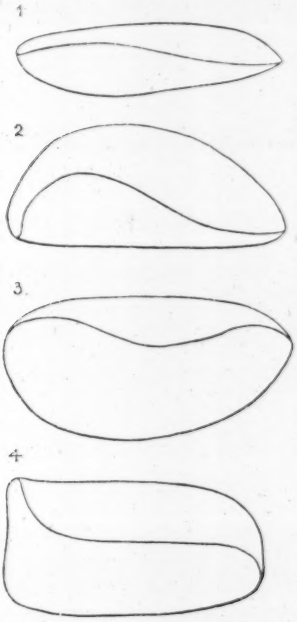


Fig. 2.

Fig. 2. Types of ridge-curves in dreikante shown in plan. The type figured in No. 3 is often so modified at each extremity by branching that instead of having two upper faces the dreikante has four.

The dreikante are usually formed from quartz pebbles derived from the Nubian Sandstone, but flints from the Eocene, granites and porphyries from the mountains, and some dolomitic limestone also furnish supplies. The most perfect examples are produced from the quartz pebbles and from a fine-grained red felsite.

The locality is almost an ideal one for such an investigation, since the wind blows almost invariably from one quarter (north, or a little west of north). At the outset I was struck by the fact that the long axes of the dreikante were not usually set in the direction of the prevailing wind. This led me to work carefully and systematically over a limited area. I marked out a portion of fairly level desert,

something under half a square mile in extent, and noted with regard to all the dreikante I could find exactly how they were situated with regard to the wind. I noted between 300 and 400 specimens, and found that 78 per cent. were set approximately at right angles to the direction of the prevailing wind, whilst only 22 per cent. were set approximately parallel to that direction. Evidently the theory already stated will not account for these facts. Moreover, not all the wind-worn pebbles were three-edged, though there seems to be a tendency towards the Brazil-nut shape in the late stage of erosion in all cases.

Stones were found in all stages, from the well-rounded, water-worn pebbles from the Nubian Sandstone (Pl. XXXI, Fig. 1), or angular flints and broken pieces of igneous rock, showing only incipient traces of the abrasive action of the wind-blown sand, to dreikante, worn down until almost level with the surface of the desert (Pl. XXXI, Figs. 7 and 8). The series shown in Pl. XXXI, Figs. 1–8, gives an almost complete 'life' history of the dreikante from the earlier stages to the last.

The ridge along the crest is rarely a straight line, but is more usually a more or less delicate curve. In the Text-figure (Fig. 2) Nos. 1 and 2 are the more usual types of curve. The side of the stone facing the wind is always beautifully smoothed and polished, presenting a clean, fresh surface to the wind. Frequently this face is the only one showing signs of cutting by the sand, the remainder of the pebble showing the original water-rounding, and is also usually stained, probably with iron oxide. This shows that in such cases the pebble has not been moved by the wind since it was exposed to the action of blowing sand, for if such had been the case other faces would have been cut upon it. Such pebbles usually present a ridge-line like Text-fig. 2, Nos. 3 or 4.

The face presented to the wind is not a plane surface, but is also gently curved. Measurements taken from over fifty specimens showed that this surface makes an angle with the vertical which varies between 40° and 50°. It most usually approximates to 45°. The curve is shown in Text-fig. 2, No. 4.

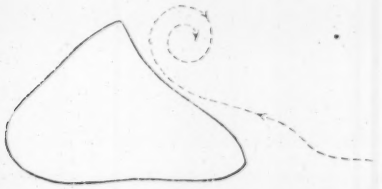


Fig. 3.

We are now in a position to consider how the dreikante have been formed. Evidently in most cases the travelling sand-grains do not, on encountering a pebble, split into two currents which travel along the sides of the stone and so form a ridge. Instead of this they tend to move upwards over the pebble with an eddying motion. The curve produced nearest the ground is always convex towards the wind.

'mûkaute,' showing beautiful wind-cut curves : Eastern Desert of Egypt.

(See Text-fig. 3.) This is probably explained by a zone of compression in the air at this point causing most of the grains to rise a little before they would otherwise do so. They apparently glide upwards over this zone in a path which is convex towards the wind. The action of the wind drives them forward against the face of the stone from which they rebound, describing what appear to be parabolic curves. The large dreikante shown in Plate XXXII is an excellent example, showing beautiful wind-cut curves.

It seemed to me that from a measurement of these curves one might be able to deduce some law with regard to the action taking place. I attempted the task, but though I was able to prove that they were parabolic, I was unable to obtain any good result, probably owing to the inaccuracy of my methods in transferring the curves on the faces of the stones to paper. This proved to be a task requiring very delicate instruments. There seemed, however, to be some similarity between the curves from the faces of different specimens, and it should be possible, I think, to obtain from them a measure of the velocity of the wind and the energy expended in erosion. The presence of stones and pebbles near to one another cause various modifications of the simple case. Side currents, eddies from other stones, all produce these effects, and these can be traced on the dreikante under consideration when examined in situ.

But how are we to explain the Brazil-nut shape? The cutting away of one face only is not enough to do that. The cutting away, however, continues until the pebble stands on a very narrow base in almost unstable equilibrium. A little extra wind and it is blown over, and the cutting commences again on a fresh side. Evidences of this are quite common on the desert. Sometimes at night the rattling of the pebbles moving under the action of a high wind is very considerable. The five-faced pebble shown in plan in Text-fig. 4 could not be explained by the earlier theory. It was originally a partly developed dreikante which has been twisted at right angles to its original direction and the abrasive action continued.

Fig. 4.

Most of the well-developed dreikante show a kind of spiral twist in the direction of their long axis. This appears to show that the path of a particle in a wind eddy is not a very simple curve. There are a good many curiosities in the formation of dreikante which are

certainly produced by the action of eddies. They would probably produce interesting results when studied by a well-trained physicist on the spot. The last stage in the formation of dreikante is reached when the pebble is reduced to an almost flattened little plate, which is sooner or later reduced in size to a mere sand-grain. Again, one can observe this reduction in all stages on the desert. Actual experiment with laboratory conditions proved that these three-edged stones could not remain with their pointed ends facing a strong air current, but that they invariably tended to set themselves broadside on towards it. This is consistent with the explanations given above, and to some extent confirms them.

The following short bibliography will perhaps be useful to those who are interested in these and other kindred phenomena:—

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4. J. H. Woodworth. *Amer. Journ. Sci.*, 1894, xlvii.
5. Verworn. "Sandschliffe von Djebel Nakûs, ein Beitrag zur Entwickelungsgeschichte der Kantengerölle": Neues Jahrb., 1896, i, p. 200.
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9. M. Choisy. *Documents relatifs à la Mission dirigée au Sud de l'Algérie*, 1890, p. 327.
10. T. Barron & W. F. Hume. *Topography and Geology of the Eastern Desert of Egypt*; Cairo, 1902.

See also F. A. Bather, "A wind-worn Pebble in Boulder-clay," Geol. Mag., 1905, p. 358; and "Wind-worn Pebbles in the British Isles, etc.", Proc. Geol. Assoc., vol. xvi, pp. 396–420, pl. xi, 1900 (with references to eighty-seven papers on dreikante and other wind-polished stones).

V.—On some supposed *Pholas*-borings from the Shores of Birket el Qurûn, the ancient Lake Moeris, of the Fayûm, Egypt.

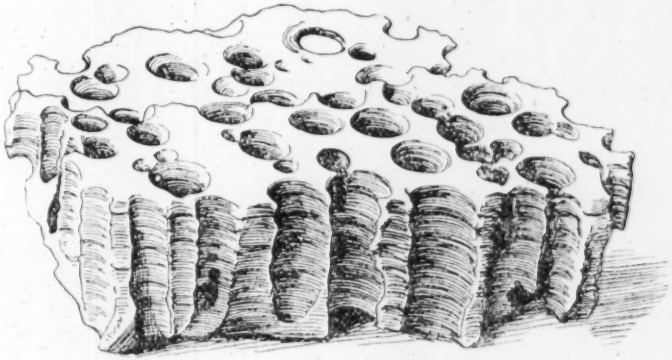
By Henry Woodward, LL.D., F.R.S.

In a review of Mr. H. J. L. Beadnell's important Memoir on the Topography and Geology of the Fayûm Province of Egypt, published by the Egyptian Geological Survey in 1905,[1] I briefly referred in passing to some "curious blocks of sandstone, pierced by numerous borings", described by the author, and I added, "they appear to be the exact replica of specimens brought home from Lake Tanganyika by Mr. J. E. S. Moore" (p. 519).

Mr. Beadnell writes in his memoir at p. 71—"*Borings on Rock-surfaces; of doubtful age.* There are within the Fayûm depression numerous rock-surfaces pierced by borings, apparently the work of marine boring mollusca but naturally offering no exact evidence as to their age and origin. These borings are found at two distinct levels, approximately from zero to 20 metres above sea-level and at 112 metres above sea-level.

[1] See Geol. Mag., 1905, pp. 516–19.

"(*a*) *Low-level borings.* Between Tamia and Dimê, near the eastern end of the Birket el Qurûn, the lowest ground, consisting of poor sandy land with tamarisk scrub, bordering the lake and cultivation [the lake] is bounded by a low escarpment of beds of the Birket el Qurûn Series. Along certain horizons one or more beds of calcareous sandstone weather into large globular masses, which, as already pointed out, are in reality huge concretions,[1] but which may have been further rounded by water action. The chief point is, however, the fact that these blocks are honeycombed in the most remarkable way by beautiful examples of borings; their presence was first noticed by Schweinfurth. The globular masses of sandstone, often several feet in diameter, are worn on the surface into a number of parallel ledges, each of which is perforated by countless numbers of *vertical holes*, averaging 10 mm. in diameter (maximum 15 mm.), placed at right angles to the ledges; these holes are not, as a rule, connected from one ledge to another. They occur in every stage of perfection, from hollows as small as the finger-tips and only a few millimetres deep to long complete chambers which generally show considerable tapering, and are often placed so close together that the dividing wall is pierced [see woodcut].



"Block of sandstone pierced by numerous borings," reproduced from Mr. H. J. L. Beadnell's Topography and Geology of the Fayûm Province of Egypt (Cairo, 1905), p. 72, fig. 7.

"At El Kenisa, a promontory jutting out into the lake, sandstones showing shell-borings occur at a height of 14 metres above sea-level. Between Dimê and the lake a calcareous sandstone contains many borings, 66 metres above the lake-level or about 22 metres above sea-level.

"(*b*) *High-level borings.* Further west, but at a considerably higher level, borings are again met with. In this case a hard compact limestone, forming a dip-slope surface on the top of the lower cliff of the Qasr el Sagha Series, was found pierced with borings, similar in character to those of the lower level. The exact locality where these high-level borings were observed is 14 kilometres west of the western end of the lake and 16 kilometres north-east of the eastern extremity

[1] See *infra*, p. 401.

of Gar el Gehannem. The height was determined as 156 metres above the Birket el Qurûn, or 112 metres above sea-level, and we have every reason to believe these figures to be approximately correct. Up to the present time borings at this altitude have not been met with in any other locality."

In Mr. J. E. S. Moore's book *To the Mountains of the Moon*, Tanganyika Expedition, 1899–1900 (published 1901), p. 160, the author writes—"The water's edge [of Lake Kivu] is generally fringed with bushes and *tall reeds*, which grow thickly together, and the land rises so steeply into the grass slopes behind that it is exceedingly difficult to get on shore at all from a boat. In consequence of this peculiar character of the shores there are hardly any places where there are sand-beaches or rocks, and it was only after I had been paddling about for an hour, and scanning the innumerable islands with my glasses, that I saw a low rocky shore on the left, on which I landed. It was a most extraordinary place, backed up by a steep green hill. The rocks which I had seen consisted of strange rounded masses like the surface of a pudding, and, wherever they were wet by the ripples of the lake, were covered with green *Cladophora* and slime, and in places they rose up into weird stony trunks, like those on the old coral beaches one sees about Mozambique. These upstanding lumps were, moreover, *pierced with holes*, as if they had been prepared for blasting operations, and for the life of me I could not find out for a long time what they were or how they had been formed. When I broke off a portion, moreover, I found to my intense surprise that the stone was full of fossil shells; there was an unmistakable *planorbis* and some conical forms, probably *melanias*. But what animal had bored the *long straight holes*, about an inch in diameter, which ran parallely through the mass? I could not make this out, but after a time I found one mass with an old partially fossilized reed-stem filling up one of the holes, and then the mystery was suddenly solved. The holes were the casts, in a lake deposit of some kind, of reeds that had once grown there. That this was so soon became certain, for I found several clumps of old dead reed-stems already becoming covered up with a curious incrustation from the waters of the lake which forms about them, and other similar structures. In other places this substance, which turns out to have a high percentage of carbonate of magnesium, binds the loose pebbles of the shore into masses of conglomerate, which are as hard as if they had been made of Roman cement" (p. 160).

Having been so fortunate as to have seen and examined the specimen sent home by Mr. Beadnell and figured above, and also the hand-specimen from Lake Tanganyika obtained by Mr. Moore, I may venture to pronounce upon the identity in their character, and to express the opinion that the perforated blocks from the Fayûm are not the work of boring mollusca in rock, but that the sandy calcareous material, which is similar to that from Lake Tanganyika, has been accumulated around the stems of reed-like water-plants as a more or less concretionary deposit precipitated from the waters of the present lake or from those of its more extensive predecessor, Lake Moeris, around the shores of which grew in abundance large clumps of these tall reeds

with hard siliceous stems,[1] the final decay of whose upright stems have left the hollow cylindrical cavities which suggested to my friend, Mr. Beadnell, the resemblance to the crypts of boring Mollusca.

Dr. C. W. Andrews, F.R.S., who has paid several visits to the Fayûm in search of fossil mammalia, informs me that the tall *Arundo*-like reeds always grow in large clumps along the margin of the lake, and that the huge concretions, or globular masses of sandstone—honeycombed with vertical borings—represent in all probability the actual bases where these reeds formerly grew.

He suggests that the accumulation which had been originally formed in the interstices between and around their thickly growing reed-like stems, was largely composed of the fine grains of sand-dust blown by the prevailing winds, and which had since become solidified into a concretionary sandstone by the addition of calcareous and saline matter contributed by the waters of the lake itself.

On this point Mr. Beadnell observes (p. 13, op. cit.): "Although under the present desert conditions practically no material from the surrounding desert is washed into the lake, doubtless a considerable amount of fine dust and sand is carried into it by the wind, especially during the violent sandstorms which occur frequently in the locality. The high cliffs which bound the northern shore of the lake, throughout a portion of its length, probably have the effect of checking the velocity of both north and south winds, thus causing a considerable amount of sand, which would otherwise be carried across, to be dropped on its surface" (p. 14).

The occurrence of these globular masses of concretionary sandstone, perforated by countless numbers of vertical holes, at different levels, both at and above the present margin of the lake, is readily explained as being due to the gradual shrinkage of the level of the lake,[2] which is constantly going on from evaporation and supposed underground outlets, and this, together with the quantity of water absorbed by the large area (1800 kilometres) under cultivation in the Fayûm, is probably in excess of that received by the Bahr Yusef Canal, the natural inlet from the Nile.

The vast proportion of perforations made by *Saxicava* and by *Lithodomi* generally, penetrate the rock in all directions, and offer no very close analogy to these usually straight, tubular, parallel, closely arranged hollows.

But the crypts of *Pholas crispata* are at times more regular, often forming extensive colonies, and the animals, in burrowing, less seldom invade one another's retreats. They commence as quite small crypts, but as the mollusc increases in size and the perforation deepens, it expands its chamber *laterally*, which, seen in vertical section, becomes somewhat flask-shaped with a slender neck. The lower end is rounded and has the largest diameter. Should the boring mollusc pass through the ledge and so expose the lower extremity of the

[1] See pl. xvi. View near the western end of the Birket el Qurûn, also view of the north side looking west, pl. i, in Mr. Beadnell's Memoir on the Topography and Geology of the Fayûm Province of Egypt (Cairo, 1905).

[2] Now occupying only 225 square kilometres, the whole area of the Fayûm depression, much of which was once a lake, covering about 12,000 square kilometres.

animal, it pays the penalty with its life. Most of the perforated blocks from the Fayûm show the burrows passing completely through the masses.

Pholades generally occur *between tides* from high to low water. Their burrows always hold sea-water, which is renewed with each tide. The *Pholas* is assisted by the grains of sand brought by each tide to bore downwards into the rock with its foot and so deepen its burrow. It is most improbable that *Pholades* could exist in a lake, however salt, as they require tidal action to carry on their existence. Mr. Beadnell writes, op. cit., p. 14: "The phenomenon of the extraordinary freshness of the Birket el Qurûn has been commented on by Schweinfurth, who shows that the degree of concentration of salt in a lake whose volume has been continually reduced, and to which salt has constantly been added, should be many times greater than the actual existing amount." An analysis[1] of the water at the west end of the lake (where the concentration is greatest, owing to the distance from the feeder canals) showed that the total salts amounted to only 1·34 per cent., of which 0·92 per cent. was sodium chloride.

VI.—On a Fossil Sole and a Fossil Eel from the Eocene of Egypt.

By Arthur Smith Woodward, LL.D., F.R.S., of the British Museum (Natural History).

(PLATE XXXIII.)

TWO well-preserved Teleostean fishes from the Eocene Limestone of Tura, between Helwan and Cairo,[2] have been submitted to me by Dr. W. F. Hume, Director of the Geological Survey of Egypt. They apparently represent new species, but, like most fishes of Eocene age, they are remarkably modern in type, and one seems to be referable to an existing genus. With them were found remains of two species of Percoid fishes, which are scarcely sufficient for exact determination.

1. Solea eocenica, sp. nov. Pl. XXXIII, Figs. 1, 1*a*, *b*.

A small fish measuring 5·7 cm. in total length is a true Pleuronectid, and may be compared with the diminutive species of *Solea*, already known from the Lower Miocene of Würtemberg.[3] As shown by Pl. XXXIII, Fig. 1, the upper part of the anterior half of the specimen is broken away, but otherwise it is completely exhibited in direct left side view.

The head with opercular apparatus occupies somewhat less than one-quarter of the total length to the base of the caudal fin. The maximum depth of the trunk must have equalled slightly less than half of this total length. Some of the head-bones are distinct and

[1] *A Preliminary Investigation of the Soil and Water of the Fayûm Province*, by A. Lucas, Survey Department, Cairo, 1902.

[2] W. F. Hume, "The Building Stones of Cairo Neighbourhood and Upper Egypt": Geol. Surv. Egypt, 1910, p. 44.

[3] *Solea kirchbergana*, H. von Meyer: *Palæontographica*, 1851, vol. ii, p. 102, pl. xvii, figs. 2, 3; also loc. cit., 1856, vol. vi, p. 25, pl. i, fig. 3.

can be readily identified (Fig. 1*a*). Below the base of the skull (*c.*) the pterygo-quadrate arcade is seen, the ectopterygoid having a thickened and sharply bent oral margin, and the relatively large quadrate (*qu.*) inclined forwards. The long and gently arched maxilla (*mx.*) has a large articular head in front and is slightly expanded at its hinder end. The slender, parallel premaxilla (*pmx.*) completely excludes this bone from the margin of the mouth. The mandibular ramus is short and deep, triangular in shape, with the dentary (*d.*) and articulo-angular (*ag.*) taking about equal shares in its constitution. The only teeth clearly distinguishable are very minute points on the oral border of the dentary. The pre-operculum (*pop.*) is sharply bent, with the upper and lower limbs of equal size, each tapering to a point. Its hinder border is rounded at the angle, and its smooth outer face is marked with four large openings into the slime-canal. The small operculum and sub-operculum are somewhat displaced, and there are traces of about six branchiostegal rays below. Nine vertebræ can be counted in the abdominal region, and two of the centra exhibit the lateral median longitudinal ridge. The minute ribs cannot be seen, but the large hypapophyses are conspicuous below the six posterior centra, slightly increasing in size backwards. There are twenty-two caudal vertebræ, and the neural and hæmal arches are long and slender. The hindmost caudal centrum bears the complex of hæmal and neural arches for the support of the caudal fin shown in Fig. 1*b*. The long and slender left clavicle is well seen (Fig. 1*a*, *cl.*), bent forwards at its upper end, slightly expanded below, and there are traces of the pair of small rod-shaped pelvic fin-supports (*plv.*) among the scales postero-inferiorly. The rays of the paired fins are not recognizable with certainty, but the anal and caudal are well displayed, and the hinder part of the dorsal is also seen. The rays of the anal and dorsal fins are remarkably slender, and those of the anal are thirty-six or thirty-seven in number. The foremost anal fin-support is a long curved bone forming the hinder border of the abdominal cavity. The caudal fin, which is rounded, comprises about eighteen rays, of which the first three at the origin above and below are short and comparatively stout, closely adpressed and gradually increasing in length. The principal caudal fin-rays are distantly articulated and bifurcate distally. The trunk is completely covered with a dense squamation, which seems to extend slightly over the base of the dorsal and anal fins. Though not easily observable, the scales are evidently antero-posteriorly elongated, and there are sometimes traces of a fringe of slender denticulations at their hinder border.

As already suggested, the fish now described is most closely similar to the small *Solea kirchbergana* from the Lower Miocene of Würtemberg, and, like that species, it appears to differ only from the typical existing *Solea* in the comparative shortness of its caudal region. In the latter respect it corresponds with the allied existing genus *Achirus*, which has curiously modified pelvic fins.[1] As, however, the

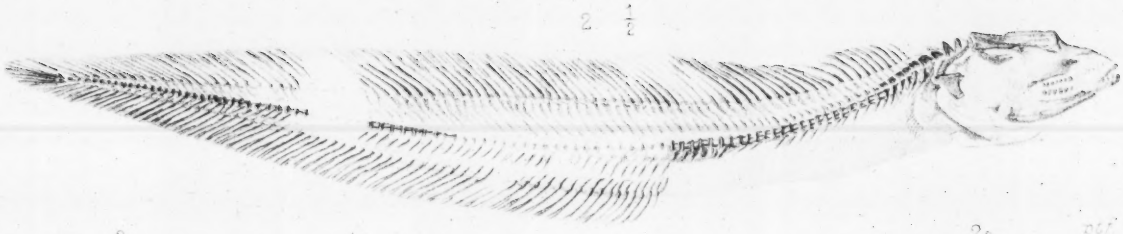
[1] D. S. Jordan & D. K. Goss, "A Review of the Flounders and Soles (Pleuronectidæ) of America and Europe": Ann. Rep. U.S. Fish. Comm. for 1886 (1889), p. 308.

jaws and the tail of the new fossil are proved to agree exactly with those of *Solea* itself, while the condition of the pelvic fins is uncertain, it may best be placed in this genus. It is distinguished from all the known species by its shape and by the number of its caudal vertebræ and anal fin-rays. It may therefore be named *S. eocenica* in allusion to the fact that it is the first example of its genus to be obtained from a formation so old as the Eocene.

2. Mylomyrus frangens, gen. et sp. nov. Pl. XXXIII, Figs. 2, 2*a*–*c*.

An eel measuring about 31 cm. in total length is well displayed from the right side, and lacks only the anterior part of the snout (Fig. 2). The length of the head with opercular apparatus equals about twice the maximum depth of the trunk, and is contained six times in the total length of the fish.

The crushed hinder half of the skull (Fig. 2*a*) shows that it is of the usual elongated, narrow, and depressed shape, with a prominent postfrontal bone (*ptf.*); and in the middle of both upper and lower jaws there is a single regular series of very large grinding teeth, which are enamelled, smooth, rather deep, and flattened at the apex. A more slender blunt tooth is seen near the symphysis of the mandible. The thin smooth operculum (*op.*) exhibits a horizontal strengthening ridge on its inner face. Traces of very slender branchiostegal rays (*br.*), not curving upwards round the operculum, are seen below. There are thirty-three vertebræ in the abdominal region, with constricted centra which are strengthened by a few slight longitudinal ridges. In about the twelve foremost vertebræ the neural spines (*n.*) are much expanded, the two first also comparatively deep, but further back they soon become slender rods like those of the caudal region. The broad triangular transverse processes are preserved both in some of the foremost and five of the hindmost abdominal vertebræ, and there are also some traces of short delicate ribs. There are about sixty-seven caudal vertebræ, with similar but more elongated centra, and very delicate neural and hæmal spines. The terminal vertebra bears a small fan-shaped expansion, suggestive of a hypural bone. In the pectoral arch the supraclavicle (*scl.*) is a relatively long and slender bone, nearly reaching the occiput; and the almost equally slender clavicle (*cl.*) bears in its upper half a delicate and much-expanded scapular arch, of which the coracoid (*co.*) forms the largest share. Of the pectoral fin only an obscure impression of the base is shown. The median fins are remarkably deep, continuous round the tail, with all the rays subdivided and distantly articulated in their distal half. The dorsal fin arises immediately above the scapular arch and comprises about ninety rays. The expansion at the end of the terminal caudal vertebra bears eight or nine comparatively crowded rays. The anal fin, which extends as far forward as the end of the abdominal region, consists of about sixty-five rays. The median fin must have been continuous round the end of the tail, but the space separating the terminal group of crowded rays from the last dorsal and anal rays respectively is greater than that between any two other fin-rays (Fig. 2*b*). There are no traces of scales in the lower part of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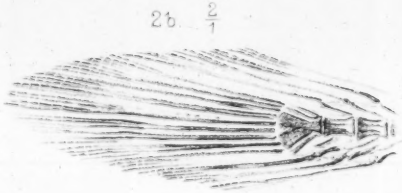
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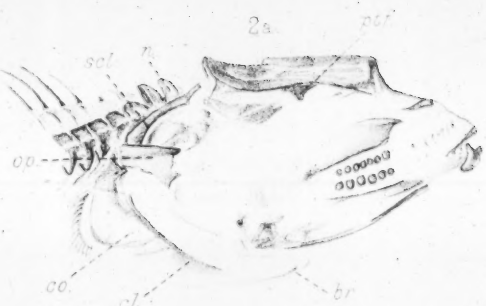
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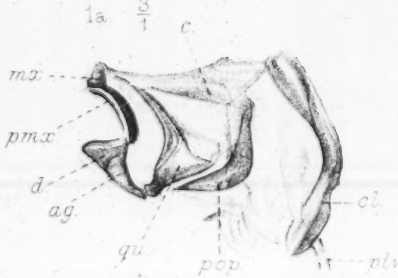
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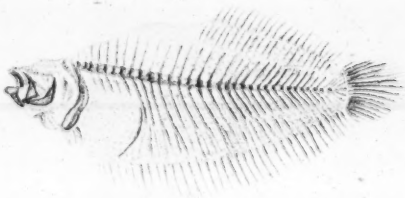
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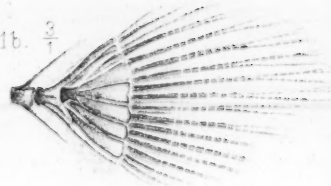
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the abdominal region, but above the vertebral column there are remains of calcifications along the lateral line; while both here and over the whole of the caudal region there is a curious mottling (Fig. 2*c*) suggestive of a fine and delicate squamation.

Though in all respects a typical eel, the fossil now described evidently represents one of the more generalized and primitive forms of the group. Its relatively large supraclavicle, its conspicuous hypural bones, as well developed as those of a very young *Anguilla*,[1] and its extensive squamation, are all characters of low degree. The relatively great depth of its dorsal and anal fins is also noteworthy. Among known primitive eels it is distinguished by its large and powerful crushing teeth, and it may therefore be referred to a new genus under the name of *Mylomyrus*. The species, defined by its general proportions and by its vertebral and fin formula already detailed, may be known as *M. frangens*.

EXPLANATION OF PLATE XXXIII.

Fig. 1. *Solea eocenica*, sp. nov.; fish nat. size, with head (1*a*) and caudal fin (1*b*) enlarged three times. Eocene: Tura, near Cairo.

Fig. 2. *Mylomyrus frangens*, gen. et sp. nov.; fish one-half nat. size, with (2*a*) head, etc., nat. size, (2*b*) caudal fin enlarged twice, and (2*c*) portion of trunk showing scales, enlarged twice. Ibid.

ag. articulo-angular; *br.* branchiostegal rays; *cl.* clavicle; *co.* coracoid; *c.* cranium; *d.* dentary; *mx.* maxilla; *n.* neural spine; *op.* operculum; *plv.* pelvic fin-supports; *pmx.* premaxilla; *pop.* preoperculum; *ptf.* posttrontal; *qu.* quadrate; *scl.* supraclavicle.

VII.—Note on a Section in probable Bagshot Beds on Shooters Hill, Kent.

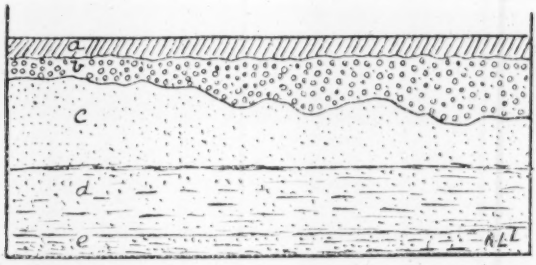
By A. L. Leach.

In 1905 trenches for electric mains were carried up the north-eastern slope of Shooters Hill, along Shrewsbury Lane to "The Bull", and thence down the western hill-slope along the Dover Road. From about 350 O.D. in Plum Lane to 424 O.D. at "The Bull" the trench ran for nearly two-thirds of a mile along the junction of the London Clay with the overlying group of sands, pebbles, and clayey gravels which form the 'gravel cap' of Shooters Hill. Neither the exact age of these superficial deposits nor their mode of formation—whether marine or fluviatile beds—is as yet known, but the general coarseness of the sands, the presence of pebbles of Lower Greensand chert, and the very stiff clayey matrix of the gravel distinguish them from typical Bagshot Beds, and moreover throughout the greater part of the section a sharp and irregular junction could be traced between them and the brown London Clay. At a few points, however, the top of the London Clay was seen to pass into pale-brown and yellowish sandy clays, sometimes of significant thickness. Thus in the Dover Road, about 100 yards above Christ Church, below the thick red clayey gravel of the 'cap', lay about 3 feet of yellow loam, the lower part of which became a pale-brown clay passing quite

[1] J. A. Ryder, "On the Origin of Heterocercy": Ann. Rep. U.S. Fish. Comm., 1884 (1886), p. 1051, pl. iv, fig. 4.

gradually into normal blue or brown London Clay with septarian nodules. In the same series of excavations (1905) a trench at the junction of Shrewsbury Lane with the Dover Road showed the Shooters Hill gravel resting irregularly on a bed of fine clean yellowish sand quite unlike anything previously noted in the numerous pits and trenches opened upon the Hill, but as unfortunately the trench was only a few feet deep the relation of this fine sand to the London Clay could not then be made out.

From the evidence of these sections I was led to think that patches of Bagshot Beds still remained beneath the 'gravel cap' on Shooters Hill, but until the present year no opportunity occurred of confirming this view. In July a sewer trench 12 feet deep was fortunately opened on the summit of the hill (424 O.D.) in the main road a few yards south-east of "The Bull", and the section displayed in this trench afforded what seems to me quite satisfactory proof of the existence of Bagshot Beds in fair thickness at this point.



Section of Bagshot Beds on Shooters Hill, Kent. *a*, road-metal; *b*, Shooters Hill gravel in reddish clay; *c*, very fine pale-buff sand; *d*, yellow and orange loamy sand; *e*, pale-brown loam and clay. Length of section, 20 feet. Vertical scale, $\frac{1}{5}$ inch to 1 foot.

The new section, which remained open only a few days, showed, beneath the road-metal, from 1 to 3 feet of red clayey gravel with a very irregular base, resting sharply upon a bed of very fine pale buff sand without a trace of pebbles. Under the centre of the road this sand was 5 feet thick; it passed downwards quite evenly into 3 feet of fine loamy sands, orange and yellow in colour, and quite without pebbles, and these in turn became more clayey and browner in colour and finally indistinguishable from ordinary brown London Clay. The total thickness of the loams and sands below the 'gravel cap' probably does not exceed 11 or 12 feet; the proofs of their Bagshot age depend on—

1. The quite gradual passage from and conformable junction with the London Clay.

2. The fineness of material and even bedding of the loams and sands, which differ in these respects very markedly from the very coarse, pebbly, and confusedly bedded sands of the 'gravel cap', and resemble the loams and sands of the probable Bagshots in Sheppey.

3. The very sharp and irregularly eroded junction between these fine sands and the 'gravel cap', which rests sometimes on the London

Clay, sometimes on the Bagshots. The Bagshot Beds, equally with the London Clay, lie below the irregular plane of erosion which forms the base of the 'gravel cap'.

In horizontal extent this thick patch of Bagshots may not cover more than a few square rods or acres at most. On the western slope of the hill it is certainly cut into deeply by the later gravel. In none of the writings of Trimmer, Goodchild, Prestwich, Spurrell, nor of Mr. Whitaker, who have all described the Shooters Hill sandy and clayey gravels from numerous old exposures, can I find any references to loams and sands like those described above, nor have I seen in many trenches and pits examined, during the last seven years, on the summit and slopes of the Hill any indications of other thick patches of similar beds. Although it therefore seems certain that the Bagshot Beds are confined to a small area on the very summit of the Hill, the interest of the patch is twofold. Firstly, it forms a link between the Bagshots of the main area and those at Hensbrook in Sheppey; and secondly, the height of the top of the London Clay can be definitely stated as 412 O.D. The basement pebble-bed of the London Clay was exposed in 1905 at about 240 O.D. at the junction of Well Hall Road and the Dover Road, half a mile from the section showing the top, described above. It has hitherto been impossible to estimate the true thickness of the London Clay of Shooters Hill, since it was not known that the top of the deposit remained beneath the 'gravel cap'. When the easterly dip through the Shooters Hill has been found an accurate estimation of the true thickness will be obtainable.

VIII.—On a Pygidium of *Bronteus* from the Devonian of Gerolstein, Eifel, preserved in the collection of the late Mr. Townshend M. Hall in the Athenæum, Barnstaple.

By Henry Woodward, LL.D., F.R.S., V.P.Z.S., F.G.S.

MANY years ago the late Mr. Townshend M. Hall, F.G.S., of Pilton, Barnstaple, specially devoted his energies to the geology and palæontology of the Devonian rocks of North Devon, and in addition to a set of fossils acquired from him, now in the British Museum (Natural History), he left a series of local fossils to the Museum in the Athenæum at Barnstaple. This collection has been kindly curated by Mr. J. G. Hamling, F.G.S., of The Close, Barnstaple, North Devon, who takes a deep interest in the geology of the district. Mr. Hamling has called my attention to an interesting specimen in this collection which proves to be a pygidium of *Bronteus*, collected by the late Mr. Townshend M. Hall in the Devonian rocks of Gerolstein in the Eifel, which country he had visited many years ago in company with the late Mr. John Edward Lee, F.G.S., of Torquay. In remembrance of that excursion Mr. Hall had presented the counterpart of this fossil to Mr. J. E. Lee, and it was supposed to be in this gentleman's collection, but it cannot now be found. There is, I believe, a good cast of the fossil in the Townshend Hall Collection in the Natural History Museum.

In his *Devonian Fauna of the South of England* the late Rev. G. F. Whidborne (Pal. Soc. Mon., pp. 32–42, pl. iii, 1892) describes and figures six English species of *Bronteus*, and remarks upon the difficulty of determining them by reason of the fact "that with the one exception of *B. flabellifer*, Goldfuss (in Mr. Vicary's collection), none of the heads and tails have occurred in contact". Besides this, the specimens are generally very imperfect, and "except in the case of the Bohemian species many of the foreign ones have been described from the pygidia alone" (op. cit., pp. 32, 33).

Although the pygidia of many species of Trilobites can hardly be relied upon for purposes of determination, those of the genus *Bronteus*, as pointed out by Barrande, are often extremely well marked and characteristic. This happens to be the case with regard to Mr. T. M. Hall's specimen of a detached pygidium from Gerolstein, and I am encouraged, therefore, to offer a figure and description of it here.

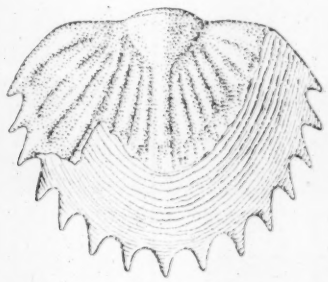


Fig. 1. *Bronteus Halli*, sp. nov. (pygidium). Lower Middle Devonian: Gerolstein, Eifel. The original specimen is preserved in the Townshend Hall Collection in the Athenæum, Barnstaple. Enlarged twice nat. size.

Description of Mr. Townshend Hall's specimen. (Fig. 1.) In outline the broadly expanded tail-shield or pygidium is nearly circular, though somewhat truncated for 20 mm. along its anterior border, where it articulated with the thorax, its extreme breadth being 30 mm. and its length 28 mm., presenting with its coalesced radiating ribs the appearance of an elegant fan. The surface is but slightly convex, with the exception of the small triangular, much elevated, central area on its anterior flattened border, which is, in fact, the distal extremity of the median axis of the trilobite, being also the point of articulation between the pygidium and the last free and movable segment of the thorax. From this triangular raised axis, which is 8 mm. in breadth and 5 mm. in length, radiate fourteen rounded ribs, seven on either side of the median raised ridge, this latter being much wider and not bifurcated; it is, indeed, a prolongation of the distal end of the triangular axis. The first rib, which forms the latero-anterior margin of the pygidium, is strongly curved downwards and is broader near its centre than the six which follow; the others are about of equal thickness; they are all more slender at first, but become gradually stouter as they approach the

margin, where they terminate in short flattened strong marginal spines. The interspaces between the ribs form smooth sulci, narrow at the anterior end, where they diverge from the axis, and broader near the flattened margin, where they gradually die out.

The shelly cuticle or crust of the pygidium has been lost along about three-fourths of its expanded margin, exposing the cast of the under surface of the caudal shield, which was covered by a series of fine, wavy, more or less parallel lines, as may also be seen upon the decorticated surface of the pygidium in *Illænus*, *Oggyia*, *Asaphus*, and some other genera.

In the genus *Bronteus* the coalesced segments forming the pygidium are usually seven in number, but two species are recorded by Barrande with only six, viz. *B. laticauda*, Wahl., and *B. hibernica*, Portl., while one species, *B. radiatus*, Munst., is said to have eight ribs in the tail-shield. The prolongation of the axis forming the median ridge to the pygidium is most commonly bifurcated [1] at or near the distal end. With very few exceptions the margin of the pygidium in the several species of *Bronteus* is smooth and destitute of spines or spinous prolongations along its border.

Mr. Townshend Hall's specimen (Fig. 1) has fifteen spines around the tail-shield, marking the terminations of the pleuræ of the seven coalesced segments which compose it, the fifteenth median spine being a prolongation of the distal end of the axis.

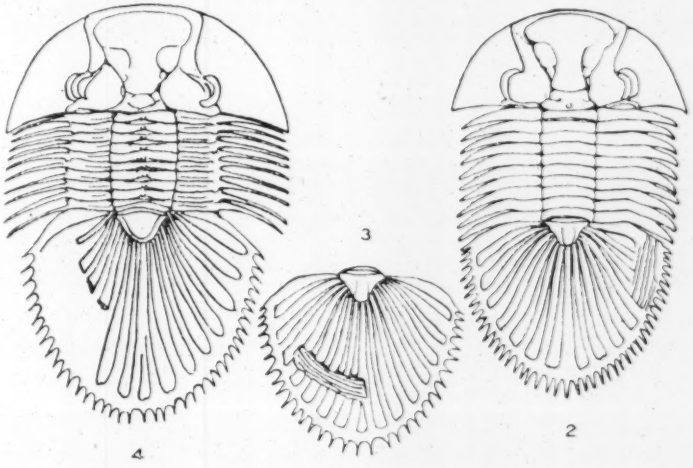


Fig. 2. *Bronteus thysanopeltis*, Barr. Upper Silurian: Bohemia. The median ridge of the tail does not appear to be bifurcated; it has forty-five marginal spines on the pygidium.

,, 3. Id. A detached pygidium, having thirty-three spines along its border. This figure has the median ridge of the tail-shield bifurcated.

,, 4. *B. speciosus*, Corda. Lower Middle Devonian. With forty marginal spines to its pygidium. This species has the median ridge bifurcated.

[1] Thirty-one species being bifurcate, and nineteen non-bifurcate.

One Upper Silurian species (Fig. 2), *B. thysanopeltis*, Barr.,[1] has as many as forty-five marginal spines on its caudal shield, while another detached pygidium shows thirty-three spines upon its border[2] (Fig. 3). *B.* (*Thysanopeltis*) *speciosus*, Corda, from the Lower Middle Devonian, has forty marginal spines around its caudal shield[3] (Fig. 4), while another Devonian form referred to by Barrande[4] has about twenty-two spines.[5]

We may, I think, safely conclude that Mr. Townshend Hall's Gerolstein specimen is quite distinct from any other Devonian form. It may be characterized as having seven coalesced segments in its caudal shield, indicated by seven marginal spines, marking the lateral termination of the pleuræ, and by a single *non*-bifurcate stout median lobe, being a prolongation of the axis of the caudal shield, and terminated by a similar median spine upon its margin. The decorticated portion of the margin of the shield shows that the underside was etched by numerous fine parallel wavy lines, extending over even the lower surface of the marginal spines.

I propose to designate this Gerolstein form as *B. Halli*, after my late friend Townshend M. Hall, who did so much good work in the Devonian rocks of North Devon.

IX.—The Characteristics of British Earthquakes: A Summary of Twenty-one Years' Work.

By Charles Davison, Sc.D., F.G.S.

FOR a detailed study of the earthquakes of any district, an interval of twenty-one years is too brief. Long-period variations of frequency cannot be established. We can form no satisfactory conception of the distribution of seismic energy in space, for some foci may lie inactive for a much longer time, while others may continue in operation without apparent change. But, to ascertain the characteristic features of the earthquakes, to investigate their relations with those which precede and follow them, or to trace their connexion with the structure of the central districts, such an interval is possibly of sufficient length. In any case, the defects resulting from its brevity may be partly compensated by uniformity in treatment and in the methods of investigation.

[1] J. Barrande, *Système Silurien du Centre de la Bohême*, pt. i, vol. i, 1852, Texte Crustacés: Trilobites, p. 843, pl. xlvii, fig. 6.

[2] Op. cit., pl. xlvii, figs. 11, 12.

[3] Kayser's *Text-book of Comparative Geology* (translated and edited by Philip Lake), p. 121, fig. 5, 1893; and Gürich, *Leitfossilien*, Tat. xlvii, fig. 1.

[4] See explanation to pl. xlvii, under fig. 12.

[5] Barrande writes—"*Bronteus acanthopeltis* (Schnur) was recently discovered in the Eifel by Professor Schnur, of Trèves. It presents the nearest analogy with *B. thysanopeltis*. It is distinguished, however, by possessing less than half the number of spines around the pygidium. It only came to our knowledge by the kindness of Professor Schnur, who was so good as to send it to us at the moment when our text was going to press." [I cannot, I regret to say, find any figure of this species.]

The earthquakes of the last twenty-one years have been in no respect unusual. None has exhibited in its central area so destructive an intensity as the Colchester earthquake of 1884. Nor has any borne a train of after-shocks so numerous as that of the Comrie earthquake of 1839. Three earthquakes (those of Hereford in 1896, Inverness in 1901, and Swansea in 1906) were, however, strong enough to cause considerable damage to buildings; and, in the low-lying country on the south side of the Ochil Hills, there have been many slight shocks which in their nature and frequency approximate towards those which have made the name of Comrie famous.

Several of the more important seismic centres in this country have lain dormant or nearly so during these years. Rumbling noises, apparently underground, are said to have been heard in West Mersea Island, off the coast of Essex, and, if seismic, may possibly be connected with the centre which gave rise to the Colchester earthquake twenty-six years ago. The Comrie focus is represented by three slight shocks, and seems to have relapsed into that state of quiescence which may precede another outburst of energy. On the other hand, the important focus in the neighbourhood of Inverness has been unusually active, and other well-known foci have exhibited those signs of flickering vitality which from time to time interrupt the monotony of our geological existence.

Hardly any part of Great Britain has been entirely free from the transitory effects of earthquake shocks, the only districts left undisturbed being the greater part of Durham and Northumberland and some of the southern counties of Scotland.

Frequency.

Taking into account only those earthquakes recorded by more than one observer, the total number which have occurred in Great Britain during the interval considered is 250, the greatest numbers in any single year being 25 in 1890, 23 in 1901 and 1906, and 20 in 1892, and the least numbers being 1 in 1897 and 1899, and 2 in 1895 and 1902. Of the total number, 50 (including two with submarine origins off the coasts of Cornwall) originated in England, 27 in Wales, and 173 in Scotland. Thus, on an average, one earthquake occurs in Great Britain every month. Also, out of every 20 earthquakes, 4 occur in England, 2 in Wales, and 14 in Scotland; or, taking area into account, 2 occur in England, 7 in Wales, and 11 in Scotland.

Intensity and Disturbed Area.

Of the 250 earthquakes, 3 were of intensity 8 of the Rossi-Forel scale, 9 of intensity 7, 7 of intensity 6, 29 of intensity 5, 64 of intensity 4, 127 of intensity 3 or about 3, while 11 were merely earth-sounds unaccompanied by any perceptible tremor. In Japan, 220 of the shocks would be described as weak, 16 as strong, and 3 as violent; in Italy, 127 would be considered slight, 64 moderate, 36 strong, and 12 very strong.

The connexion between the intensity of the shocks and the areas disturbed by them is shown in the following table:—

Table I.

Intensity.	Disturbed Area in Square Miles.		
	Maximum.	Minimum.	Average.
8	98000	33000	65900
7	63600	1000	24500
6	3100	74	1200
5	3000	90	850
4	1130	28	260
3	219	$18\frac{1}{2}$	126

The intensity at the epicentre is not, however, proportional to the energy expended in producing an earthquake, for it depends to a great extent on the depth of the focus and the nature of the surface rocks. A more satisfactory though still a rough test is the area included within a given isoseismal, say that of intensity 4.[1] If an earthquake be regarded as *strong* when this area exceeds 5000 square miles, as *moderate* when it lies between 1000 and 5000 square miles, and as *slight* when it is less than 1000 square miles, then Great Britain has been visited during the last twenty-one years by 9 strong, 7 moderate, and 223 slight earthquakes, and 11 earth-sounds.[2]

Periodicity.

The monthly distribution of earthquakes is given in the next Table (II), the upper figure denoting the number of earthquakes during the first 14 days in February and the first 15 days in each of the other months, the lower figure the number observed during the remainder of each month.

Table II.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
7	2	7	10	8	2	17	3	2	9	8	6
17	6	7	4	9	17	6	17	28	19	11	28

Applying the method of overlapping means[3] to determine the annual and semi-annual periods, it appears that there is a well-marked annual period with its maximum in October, the amplitude being

[1] The disturbed area is an unsatisfactory test, for the Pembroke earthquake of 1893 was felt over a larger area than the stronger shock of 1892, and the Derby earthquake of 1904 than the stronger earthquake of 1903.

[2] The strong earthquakes are those of Pembroke in 1892 and 1893, Hereford in 1896, Inverness in 1901, Derby in 1903 and 1904, Carnarvon in 1903, Doncaster in 1905, and Swansea in 1906. The moderate earthquakes are those of Bolton in 1889, Inverness in 1890, Leicester in 1893, Carlisle in 1901, Strontian in 1902, Derby in 1906, and Oban in 1907.

[3] Phil. Trans., 1893 A, pp. 1108–15; Boll. della Soc. Sismol. Ital., vol. iv, 1898, pp. 89–100.

·37 of the average monthly number. The semi-annual period is less pronounced, and its reality is doubtful owing to the smallness of the amplitude, which is only ·14. The analysis gives the maximum epochs in the middle of May and November.

The next Table (III) illustrates the hourly distribution of the earthquakes, those which are reported as occurring at the exact hours being divided equally between the hours before and after.

TABLE III.

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
a.m. .	9	17	6·5	10	16	9	9·5	10	8·5	9·5	10	6
p.m. .	4	10	5	7	16	9	9	6	5	11	12	9

As the shocks were not recorded instrumentally, it is useless applying the method of overlapping means to these figures. The variations in frequency are no doubt chiefly due to more favourable conditions existing at certain times of the day, as, for example, the early hours of the night (9 to 11) and the hour 1 to 2 a.m., when many persons lie awake after their first sleep. The increase of apparent frequency in these hours is manifest in every earthquake catalogue, but a feature which seems to be peculiar to British earthquakes is the large number felt from 4 to 5 p.m. Of the sixteen earthquakes recorded during this hour, seven occurred on Sunday, while two others were strong shocks that could not have passed unnoticed at any time of the day. It is, therefore, probable that the number of slight shocks recorded in Great Britain would be almost doubled if all the hours of the day were as restful as those devoted to the modern institutions of the Sunday afternoon siesta and the 5 o'clock tea.

NATURE OF THE SHOCK.

As a general rule, in British earthquakes the shock consists of a single series of vibrations, which increase rapidly in strength, until one or several of greater prominence are felt, after which they fade as rapidly away. The average duration of the shock in such cases is about four seconds, though, as in the Carnarvon earthquake of 1903, it may be as much as 6·7 seconds. In very slight earthquakes there are no prominent vibrations, and only a weak tremor is perceived; in slight earthquakes the shock often begins with a single prominent vibration, like the thud of a falling body, followed by a brief tremor as such a fall would produce in a building. In these earthquakes the average duration of the shock seldom exceeds two seconds and is often less.

In a few earthquakes the shock consists of two parts, in each of which the vibrations increase to a maximum and then die away. The two series generally differ in intensity and duration, and occasionally in the period of their vibrations. As a rule, the interval between the two parts is one of absolute rest and quiet, but occasionally it is occupied by a weak tremor and sound which are

observed only near the epicentre, so that, at a distance from that region, the shock consists of two entirely detached parts. The average duration of the interval of rest is 2·7 seconds, and that of the whole shock about six or eight seconds, rising, as in the Hereford earthquake of 1896, to 9·3 seconds. It is now known [1] that, in these cases, the double shock is caused by impulses in two distinct foci, the impulses being either simultaneous or separated by an interval which is often less than the time taken by the earth-waves to travel from one focus to the other. Of the 250 earthquakes, at least eleven (or about 4 per cent.) belong to this class of twin earthquakes.

Sound-Phenomena.

The sound which accompanies an earthquake is a deep rumbling sound, so low that it is inaudible to some persons, while to others in the same place it appears louder than any thunder. That the inaudibility is not due to inattention is clear from the fact that, in the Inverness earthquake of 1901 (which occurred at 1.24 a.m.), 86 per cent. of the observers who were awake, and 84 per cent. of those who were asleep, heard the sound which preceded the shock. For the Doncaster earthquake of 1905 (which occurred at 1.37 a.m.) the corresponding figures are 93 and 91 per cent.

Of the 250 earthquakes, 197 (or 79 per cent.) were certainly accompanied by sound. In 4 cases, the observers state that they heard no sound; in 49 cases, no reference is made to the sound-phenomena. Of these 53 earthquakes, 28 occurred in the Ochil district, 10 in Glen Garry, 11 were after-shocks of strong earthquakes, and 4 were slight earthquakes in various places. But all, without exception, were feeble tremors, the number of observers was small, and there can be little doubt that, with a larger number, there would have been some who would have heard and recorded the sound. It is probable, therefore, that all British earthquakes are attended by audible vibrations.

In strong earthquakes the sound was heard on an average by 83 per cent. of the observers, in moderate earthquakes by 93 per cent., and in slight earthquakes by 97 per cent. This difference is partly due to the fact that, in slight earthquakes, the sound is generally a much more prominent feature than the shock, and partly to the variable size of the sound-area. In slight earthquakes, the sound-area either coincides with or overlaps the disturbed area; in moderate earthquakes, the two areas are approximately coincident; in strong earthquakes, the sound-area falls short of the boundary of the disturbed area, the sound-area varying from 43 per cent. of the disturbed area in the Derby earthquake of 1904 to 82 per cent. in the Inverness earthquake of 1901. On an average, the sound-area is 64 per cent., or roughly two-thirds, of the disturbed area.

In moderate and slight earthquakes, the percentage of audibility is practically uniform throughout the area affected. In strong earthquakes, with a large disturbed area, the decline in audibility as the

[1] Quart. Journ. Geol. Soc., vol. lxi, 1905, pp. 18–33.

sound-waves recede from the centre is distinctly marked. Within the central isoseismal, 97 per cent. of the observers on an average hear the sound, and in the successive zones bounded by the isoseismals, the average percentages of audibility are 94, 88, 69, and 60 respectively. Close to the boundary of the sound-area, there is a rapid decline to zero.

The sound may be classified under one of the following types: (1) Wagons, trains, traction-engines, etc., passing, (2) thunder, (3) wind or a chimney on fire, (4) loads of stones falling, (5) the fall of a heavy body, (6) explosions, and (7) miscellaneous sounds, such as the trampling of many animals, the roar of a waterfall, etc. The following Table (IV) shows the average frequency of reference (in percentages of the total number) to these different types for the three classes of British earthquakes. In the last two lines of the table are given separate figures for two divisions of slight earthquakes, the first division having a long focus and the second division a short focus.

TABLE IV.

Earthquakes.	Type.						
	1	2	3	4	5	6	7
Strong	46	24	10	5	3	7	5
Moderate	49	26	4	5	5	8	3
Slight	33	29	5	7	9	14	3
,, (long focus) . .	40	37	4	1	4	10	4
,, (short focus) . .	29	26	6	9	11	16	3

Omitting the seventh type, the first three may be regarded as of long and the next three as of short duration. The percentage of reference to types of short duration is 16 for strong earthquakes, 19 for moderate earthquakes, 31 for slight earthquakes, or 16 for slight earthquakes with a long focus and 37 for those with a short focus. It will be noticed that the sounds attending strong and moderate earthquakes, and also slight earthquakes with a long focus, are approximately of the same character.

In the neighbourhood of the epicentre, the sound varies greatly in character and intensity. When the shock begins, the sound becomes deeper and more rumbling, and with the strongest vibrations deep booming explosive crashes are heard by those observers who possess a low limit of audibility. In the zone outside the central isoseismal the crashes are less frequently heard, but still the sound changes perceptibly while the shock is felt, becoming rough and grating: while, near the boundary of the sound-area, it is a low monotonous moan like the boom of very distant thunder. Table V shows the variation in type in strong earthquakes, beginning with the central zone A, and continuing with the zones B, C, D, E, bounded by successive pairs of isoseismals.

TABLE V.

Zone.	Type.						
	1	2	3	4	5	6	7
A	36	30	6	8	3	12	4
B	44	28	9	6	5	7	5
C	50	22	11	4	5	5	4
D	47	21	15	3	4	4	5
E	47	21	25	1	1	1	1

Thus, as the distance from the origin increases, there is a steady diminution in the references to types 2, 4, and 6, an increase in those to type 3, and on the whole an increase in those to type 1.[1] Omitting type 7, the percentage of references to the types of long duration (1 to 3) for successive zones are 76, 81, 86, 88, and 94, implying, not that the duration of the sound increases, but that the sound becomes smoother and more monotonous in the outer zones.

Occasionally, the sound is heard before the shock and becomes inaudible as soon as the first vibrations are felt. With a very few exceptions, however, the sound, when heard at all, accompanies the shock, though it is heard by many observers both before and after the shock. The time-relations of the principal epochs of the sound and shock are given in Table VI, in which the figures in the columns headed p, c, and f denote the number of records per cent. in which each epoch of the sound preceded, coincided with, or followed the corresponding epoch of the shock; those in the columns headed g, e, and l denote the number of records per cent. in which the duration of the sound was greater than, equal to, or less than that of the shock.

TABLE VI.

Earthquakes.	Beginning.			End.			Epoch of Max. Int.			Relative Duration.		
	p	c	f	p	c	f	p	c	f	g	e	l
Strong . .	66	25	9	15	40	45	22	68	10	68	27	5
Moderate . .	66	29	5	12	43	45	24	73	3	75	23	2
Slight . . .	59	34	7	14	47	40	33	67	...	58	41	1

This table shows that there is a close resemblance, as regards time-relations, between all three classes of earthquakes. Roughly speaking, two out of every three observers who hear the sound at all hear the fore-sound, two out of every five hear the after-sound, while to two out of every three the sound is loudest at the instant when the shock is strongest.

[1] The slight decrease in the two outer zones is probably due to the comparative uniformity in the intensity of the sound at great distances.

The next Table (VII) shows how slightly the time-relations of the sound and shock vary throughout the sound-areas of strong earthquakes.

TABLE VII.

Zone.	Beginning.			End.			Relative Duration.		
	p	*e*	*f*	*p*	*e*	*f*	*g*	*e*	*l*
A	67	30	3	19	42	38	70	28	2
B	69	24	7	15	42	44	69	24	7
C	70	20	10	15	44	41	66	27	7
D	63	25	12	21	44	36	54	38	8

The precedence of the shock by the sound is generally attributed to a greater velocity of the sound. If this were the case, however, the sound, with increasing distance, would be more generally heard before the shock and less frequently after it. There is no evidence whatever of such a displacement of the sound in the above Table. The only tendency distinctly noticeable is towards equality in the relative duration, and this might be expected from the gradual quenching of the weaker vibrations which constitute the fore-sound and after-sound.

MINOR SHOCKS.

The series of slight shocks which occur in Great Britain belong to two classes, one including those which have been confined to Glen Garry and the Ochil district, the other those which precede and follow the stronger earthquakes.

The Glen Garry series lasted for about ten years, from 1889 to 1899. In this interval 41 slight shocks were recorded, the majority occurring during the three years 1890–2, when the numbers felt were 11, 18, and 6 respectively. The Ochil series began in the year 1900, and is still (1910) continuing with unabated frequency. Up to the end of 1909, the total number recorded is 83, 4 having occurred in 1900, 1 in 1903, 10 in 1905, 19 in 1906, 13 in 1907, 17 in 1908, and 18 in 1909. They vary considerably in intensity. Two, namely, those of September 21, 1905, and October 20, 1908, were strong within the epicentral district, and each disturbed an area of about a thousand square miles. But they should be regarded as stronger shocks than usual, rather than as the parents of trains of after-shocks, for the slight shocks which followed were not more frequent immediately after them than at other times.

True accessory shocks are almost confined to the strong earthquakes which disturb areas of more than 5000 square miles. The total number of such shocks is 71, all but five of which attended the strong earthquakes and the Inverness earthquake of 1890, and of the majority 15 were fore-shocks and 51 after-shocks. It is worthy of notice that, as regards after-shocks, there is a marked difference between simple and twin earthquakes. The three simple earthquakes of Inverness in

1890 and 1901 and Carnarvon in 1903 were followed by 33 after-shocks, and the seven strong twin earthquakes by 18 after-shocks.

Distribution in Space.

The total number of earthquakes which it is possible to associate with known lines of fault or folding is 199.[1] Of the 199 earthquakes, 153 were probably connected with faults of the Caledonian system, 23 with Charnian, 10 with Malvernian, and 13 with Armorican faults. In Scotland, with the exception of the Loch Broom earthquake of 1892, which was connected with a Charnian fault, the remaining 129 shocks were due to movements along Caledonian faults. In England 15 earthquakes were connected with Caledonian faults, 22 with Charnian, 6 with Malvernian, and 5 with Armorican faults. In north-west and central Wales, the earthquakes were connected with Caledonian faults, in the south of Wales with Armorican faults. Of the nine strong earthquakes, the Inverness earthquake of 1901, the Derby earthquakes of 1903 and 1904, the Carnarvon earthquake of 1903, and the Doncaster earthquake of 1905 were connected with Caledonian faults, the Hereford earthquake of 1896 with a Charnian fault, and the Pembroke earthquakes of 1892 and 1893 and the Swansea earthquake of 1906 with Armorican faults. The last four earthquakes were the strongest felt in this country throughout the twenty-one years. Twin earthquakes are entirely confined to England and the south of Wales.

Origin of British Earthquakes.

The study of British earthquakes has led to the association of a large number of them with known faults, especially in those in which there is reason to think that the foci were situated at a small depth. In other cases, the investigation of the earthquakes has thrown light on the structure of the epicentral districts at depths far beyond the reach of methods at the disposal of the field-geologist. For instance, the complicated structure of the English Lake District is superposed on one of a more simple character, the Carlisle earthquakes of 1901 having originated in a fault not less than 23 miles in length, and directed approximately N. 5° E. Similarly, in south Glamorgan, as shown by the Swansea earthquake of 1906, a fault at least 22½ miles long runs in a direction about E. 5° N. from west of Swansea to the neighbourhood of Llwynpia.

A rough approximation to the length of the seismic focus is given by the difference in length between the longer and shorter axes of the innermost isoseismal.[2] In estimating the average length of the focus for the different classes of British earthquakes, after-shocks are omitted, as in them the length of the focus is governed to some extent by that of the principal earthquake. The results are as follows:—

[1] The earthquakes omitted are the 41 shocks felt in Glen Garry from 1889 to 1899, 2 shocks near Tadcaster in 1890, 5 in Pembrokeshire in 1893, 3 in Annandale in 1894 and 1896, and 1 near Beddgelert in 1904.

[2] Gerland's *Beitrage zur Geophysik*, vol. ix, 1908, p. 224.

TABLE VIII.

Earthquakes.	Mean length of focus in miles.
Strong . .	12¼
Moderate . .	13
Slight, *a* . .	12
,, *b* . .	4¼

Slight earthquakes are obviously divisible into two sub-classes, the first in which the focus is 9 miles or more in length, the second in which the focus is 6 miles or less in length.[1] The above Table gives the reason why the sound should be of nearly the same character in strong, moderate, and the first division of slight earthquakes. Thus, the intensity of all but the slightest earthquakes depends, not on the magnitude of the focus, so much as on the amount of relative displacement along the surface of the fault.

British earthquakes, according to the nature of the shock, are divisible into two classes, simple and twin, and this classification corresponds to a difference in origin. Simple earthquakes are due to continuous slips, as a rule along strike faults; twin earthquakes are caused by rotation of the median limb of a crust-fold along a transverse fault, the two foci coinciding with the crest and trough of the fold, the interfocal region with the practically undisplaced portion of the median limb about which the rotation takes place. In this connexion, it is worthy of notice that the average distance between the epicentres of British twin earthquakes is 10 or 11 miles, which agrees closely with the average distance of 9 to 12 miles between the crests of the great crust-folds in France.

The average length of the focus in twin earthquakes is about 12 miles. Thus, the average length of focus in twin earthquakes and in other earthquakes, whether strong or moderate or, in certain cases, slight, is nearly the same, and is probably equal to, or it may be slightly more than, the average distance between the crests of the crust-folds. In other words, the magnitude of the crust-folds seems to determine the length of fault-slips along strike faults as well as along transverse faults.

NOTICES OF MEMOIRS.

I.—The Significance of Early and of Pleistocene Glaciations.[2] By Marsden Manson, Ph.D.

THE objects of this paper are to point out the significant differences between the preceding, accompanying, and succeeding phenomena of early glaciations and the corresponding phenomena of Pleistocene

[1] In determining the average for the second sub-class, a large number of very slight shocks were unavoidably omitted; their inclusion would, of course, lower the average considerably.

[2] Being an abstract of a paper read before the Eleventh Session of the Int. Geol. Congress, Stockholm, August, 1910.

and present glaciation. One of the broadest and most recent summaries on the subject is that of Professor T. W. Edgeworth David, F.R.S.[1] He finds that in the following horizons the presence of evidences of extensive ice-action is quite firmly established:—Lower Cambrian, Devonian, Permo-Carboniferous, Pleistocene.

Professor A. P. Coleman also reviews the whole subject very clearly, and finds four periods of extensive glaciations—(1) Lower Huronian, left its effects over hundreds of thousands of square miles;[2] (2) Early Cambrian, in widely separated regions; (3) Permo-Carboniferous, for large parts of the world; (4) Pleistocene, very general. We therefore accept, for the purposes of this discussion, that ice-action of great extent occurred in these periods.

Cambrian Glacial Action.—Evidences of the action of ice in Cambrian time have been observed from Arctic, through north temperate and tropical, and in south tropical latitudes. Evidences of Cambrian life have been found which are of wide distribution as to latitudes and indicative of warm seas. "The testimony of the fossils, wherever gathered, implies nearly uniform climatic conditions, not only over our own continent, but throughout all the earth where records of the Cambrian Period are found."[3] The extremely wide range of life in Cambrian time justified Dana in saying, "There was no frigid zone, and there may have been no excessively torrid zone."[4]

Evidences of Glacial Action in the Devonian Era.—When the evidences of glacial action in the Devonian era are compared it is found that they embrace nearly as wide a distribution in latitude as do the evidences of the life of that era, and that, like the distribution of temperature and of life in the preceding Silurian and succeeding Carboniferous era, both life and glacial action were distinctly non-zonal in distribution, and the former indicated warm temperate or tropical conditions.

Permo-Carboniferous Ice-sheets.—During Permo-Carboniferous time extensive sheets of ice were laid down in the tropical latitudes of both hemispheres. During this period the life was indicative of temperate conditions rather than Arctic, and its distribution was worldwide. "The Permian Period lies in the midst of geological history, with periods of great uniformity and remarkable Polar geniality both before and after it."[5]

It must be recognized at once that zones of temperature did not prevail immediately before, during, nor immediately after the Permo-Carboniferous glaciation; that whatever part solar radiation played in the climatic distribution of that age it was not the controlling part, as at present, and that to attempt to fit such a distribution of temperature to solar radiation involves suppositions and hypotheses which have not been made to harmonize with present conceptions of solar-controlled climates. The volcanic heat liberated at the close of this era, and that

[1] See Trans. Tenth Int. Geol. Cong., Mexico, vol. i, pp. 437–82, 1906.

[2] Bull. Geol. Soc. Am., vol. xix, pp. 347–69, November, 1908. See also Davis, ibid., vol. xvii, p. 414, August, 1906.

[3] Chamberlin & Salisbury, *Geology*, ii, p. 273.

[4] Manual, 4th ed., p. 484.

[5] Chamberlin & Salisbury, ii, p. 656.

slowly brought into effect from cooling lava and radio-active substances by subsequent denudation, would tend to raise the temperature of the air, from which it could escape only by slow processes[1] under the powerful conservative influences of solar radiation. The widespread geniality of the succeeding period may be, in part at least, attributed to this accession of heat—the geniality compared with that of the preceding period, when tropical life flourished at all latitudes. Taking the three epochs in succession, Carboniferous, Permian, and Triassic, it appears that the Permian was a period of marked temperature depression in a series of non-zonal climates.[2]

Pleistocene Glaciation and Conditions.—Pleistocene glaciation followed a period during which cold temperate forms of life were for the first time distinctly developed over wide ranges of latitude, which, during the immediately preceding period, were occupied by temperate forms. For the first time also marine life of Arctic habit took possession of oceans previously supporting more temperate forms only. The cold became so general as to be 'worldwide' in its effects.

A Review and Comparison of these Glaciations and of Life.—When the distribution in latitude of the evidences of early glaciations and of life are compared with Pleistocene glaciations and the distributions of modern life, it is observed—

1. That both early and late glaciations and all life prior to the modern era were distributed over extreme ranges of latitude and apparently without regard to exposure to solar radiation.

Pleistocene glaciation may have reached its maxima progressively at different latitudes, that is, whatever may have been the maximum extension of glaciation in the latitude of the tropics, this maximum was apparently reached prior to the maximum in, say, latitudes 45 to 55 degrees; similarly, glacial maxima in these latitudes may have preceded maximum glaciations in Polar latitudes. But taken as a whole, Pleistocene glaciations were not laid down in accordance with present zonally distributed climates.

2. That early glaciations were preceded, accompanied, and followed by a widespread distribution of tropical and temperate forms of life and by warm oceans, while Pleistocene glaciation was 'phenomenal', was preceded by a period of widespread cold temperate life, and accompanied by colder oceans than had previously prevailed.

3. That the earlier glaciations were followed by periods of widespread tropical or temperate life, while Pleistocene glaciation was followed by a period in which life and temperatures were restricted to zones distinctly dependent upon solar radiation for their establishment and maintenance.

A deduction which seems fully justified is that up to the culmination of Pleistocene glaciation zones of temperature were scarcely perceptible, if at all, which deduction is confirmed by both the wide distributions of life and the evidences of glacial action in low latitudes in the pre-Pleistocene eras.

The absence of distinct zones of climate is highly significant, and

[1] Chamberlin & Salisbury, ii, p. 672.

[2] Neumayr held that there were climatic zones in Jurassic and Cretaceous times; see W. T. Blanford, Address to Geol. Soc., 1890, p. 55.—Ed. Geol. Mag.

clearly established the fact that a solar control of climates similar to that at present existing did not prevail prior to the modern era,[1] or that some factor was active which did not admit of the zonally distributed climates of solar control.

The distribution of ice and of fossil life during Huronian, Cambrian, and Permo-Carboniferous time, and during preceding and succeeding eras to the close of Pleistocene time, are so widely at variance with a solar-controlled distribution of temperatures like the present that it seems impossible to assign these phenomena merely to variations in solar radiation. Under solar control, for instance, what would become of Polar and mid-latitude life while tropical latitudes were glaciated nearly or quite to sea-level?

The phenomena of geological and present climates may be interpreted under the hypothesis that prior to the Recent or Human Epoch the earth was more continuously clouded, and thereby deprived of the zonal temperature control of solar radiation.[2]

When these evidences of ice-action and the phenomena of life are broadly compared, under this hypothesis, it appears to the writer—(1) That accordingly ice-fields were laid down generally without regard to latitude, although Pleistocene glaciation reached its maximum along the broadest land areas under the north temperate rain-belt, and this maximum may have been reached after the inauguration of solar control in tropical latitudes. (2) That the earlier glaciations were contemporaneous with tropical and temperate land and marine forms, and that the greater exposure of the continents to loss of heat, and their low specific heat and conductivity, caused them to cool more readily, thus frequently forcing land animals to seek warmer conditions in the oceans, and from these permanently marine forms of life have descended. (3) That Pleistocene glaciation followed an extremely gradual although fluctuating refrigeration of the earth as a whole when its crustal condition became more stable than ever before and its oceans for the first time fully and completely chilled, and that the stress of cold was so general that the oceans did not then offer more congenial conditions to even the cold temperate land life of the immediately preceding period; that this stress was first relieved in regions of least cloudiness by the penetration of solar radiation to the surface, and that more moderate conditions spread thence into the solar-controlled, zonally distributed temperatures of to-day; that the accession of heat through continuous exposure and the trapping of solar radiation, converted into long wave-length rays, is a cumulative process which has recorded and is yet recording its gradual but irregular progressiveness by the removal of Pleistocene glacial conditions and the corresponding advance of life. (4) That only after the culmination of this marked and phenomenal glaciation did temperatures and life pass from a non-zonal to a zonal distribution, which manifests itself in zones of life and of climates, and marks

[1] There is an apparently zonal distribution of the very much mixed groups of Pliocene life which may have resulted from a similar distribution of temperatures, but exceptional conditions warn us against too implicit an acceptance of this conclusion.

[2] See Trans. Tenth Int. Geol. Cong., Mexico, vol. i, pp. 349–405, 1906.

Pleistocene time as the most significant transition epoch of the climatic history of the earth.

There seems to be a tendency in recent years to fall back upon the hypothesis of variations in the emissive power of the sun to account for the variations of surface temperatures indicated by ice formations.[1]

It is certainly quite possible and even probable that the sun's emission has altered within geological time, but neither the distribution of fossil life nor the evidences of ice formations occur with that zonal arrangement in harmony with solar-controlled climates, so that to the writer it seems necessary to attribute geological climates to a uniformly distributed source of heat, and to eliminate solar control by the reasonable assumption of persistent cloudiness. It is not implied that the clouds were so thick as to prevent the transmission of light such as is now received on overcast days, but a far less thick layer than that would suffice to screen off most of the solar-heating effects. Moreover, under the hypothesis that solar radiation was interrupted by a thin but continuous stratum of cloud, there is no reason why glaciers should not flow into the sea at any latitude.

When cloud densities decreased to approximately present conditions the tropical zones of downcast currents and minimum cloudiness were the regions first affected, and in these solar radiation first reached the surface. Thus solar radiation which, with a continuously cloudy sky, fixed the tropical zones as regions most exposed to cold downcast currents and to glaciation, also fixes them, with present cloudiness of 52 per cent. of the earth's surface, as regions of maximum exposure to solar radiation. The great continental glaciers of the northern hemisphere were grouped about the North Polar region for the reason that continents are so grouped, and for the additional reason that atmospheric circulation fixes latitude 50° N. as one of the belts of maximum storm circulation and precipitation.

Solar climatic control distinctly manifests itself by a zonal arrangement of temperatures and of life; under this control the disappearance of Pleistocene ice-sheets is taking place. The earth is therefore not in an era of senility or decrepitude, but in the springtime of a new life in which nobler, higher types of life are being developed.

The difficulties attendant upon the previous explanation of climatic phenomena appear to the author to be due to false premises, namely, (1) that solar radiation controlled the climates of Pleistocene and previous eras; and (2) that effective earth heat, under the extremely slow processes of loss and bringing into effectiveness and the powerful processes of conservation, was entirely lost prior to the era of zonally disposed climates. Upon a rejection of these assumed premises we may freely admit that ice has been a geologic agent from the earliest ages, particularly upon land masses of low specific heat and extremely low conductivity, and that the regions of cold downcast currents were, prior to the Pleistocene, most exposed to cold downcast currents and to consequent local glaciation; and that as the supply of earth heat fluctuated, ice formed under favourable conditions over large geographic areas in any latitude and during many eras, to disappear from an

[1] Professor David, Trans. Tenth Int. Geol. Cong., Mexico, vol. i, pp. 481–2, 1906.

increase of available earth heat or a lowering of elevation. These earlier ice formations were, however, not accompanied by cold seas, nor upon their disappearance were zonally distributed climates established.

The approaching, culminating, and succeeding phenomena of the Ice Age were therefore far more remarkable and significant than the corresponding phenomena accompanying the occurrences of ice as a geologic agent in the earlier ages. The worldwide distribution of cold temperate life just preceding the equally worldwide phenomena of Pleistocene glaciation, and the succeeding era of zonally distributed temperatures and life distinctly dominated by solar control, mark a profound change in the climatic history of the earth, and make it manifest that but once have the oceans chilled to that degree of cold which warrants the use of the term Ice Age.

Summary.—The phenomena of the earlier glaciations and the preceding, accompanying, and succeeding distributions of temperatures and of life appear to warrant the conclusions—(1) That these phenomena did not occur during eras of solar climatic control; (2) that there were apparently marked fluctuations in the amounts of available earth heat; (3) that during periods of deficiency and upon elevated areas, and particularly in zones of downcast atmospheric currents, local glaciers of great extent formed; (4) that these glaciations disappeared or varied from one of several causes, (*a*) accessions of heat from the crust, (*b*) variations in the elevation of the crust, (*c*) possible intermittent thinnings of the denser cloud formation of earlier eras in the regions of minimum cloud formation, permitting solar radiation to reach the earth's surface in these latitudes; (5) that these glaciations were not of the same order of magnitude nor did they mark the climacteric era of the evolution of climates as did the Ice Age.

II.—Royal Society.—The Lignite of Bovey Tracey. By Clement Reid, F.R.S., and Eleanor M. Reid, B.Sc. Read June 16, 1910.

IN 1863 Heer and Pengelly published in the *Phil. Trans.* an account of these lignite beds and their flora. Heer classed the lignite as Lower Miocene, considering it equivalent to the Aquitanian of France and to the Hamstead Beds of the Isle of Wight. These latter are now referred to the Middle Oligocene.

A statement by Starkie Gardner, that Heer's Bovey plants are the same as those found in the Bournemouth Beds (Middle Eocene), has caused the Bovey Beds to be classed as Eocene in recent textbooks and on recent maps of the Geological Survey, leaving a great gap in the geological record in Britain. Our researches have not supported this view, but tend to show that Heer was right, the Bovey lignite being highest Oligocene, or perhaps lowest Miocene. We could find in the Bournemouth collection nothing to support Gardner's view, and he does not appear to have collected at Bovey, his comments referring to the collection now in the Museum of Practical Geology.

We therefore made a collection in the Bovey deposits, as far as the state of the lignite pit would allow, in order to settle if possible the true age. The results were unexpected, for by using new methods we obtained a considerable number of species, mainly identical with

well-known plants of the lignite of the Wetterau, which is generally classed as Upper Oligocene. In certain cases better specimens showed also that Heer's supposed peculiar species of Bovey belong to well-known forms of the Rhine lignite—his *Vitis britannica*, for instance, being only a crushed seed of *Vitis teutonica*. Several curious new species were discovered, including the earliest known *Rubus*, a peculiar *Potamogeton*, and a new genus of Borragineæ.

A study of the cone and leaf of *Sequoia couttsiæ* proves that it is a true *Sequoia*, and not a species of *Arthrotaxis*.

III.—Edinburgh Geological Society.

A GEOLOGICAL work by Dr. Ogilvie Gordon, entitled *The Thrust-masses in the Western District of the Dolomites* in South Tyrol, has just been published by the Edinburgh Geological Society in a Special Part of their *Transactions*, vol. ix; price 7*s*. The text extends to 91 pages, and is illustrated by 2 geological maps, 18 coloured geological sections, and a number of original photographs and sketches. Mrs. Gordon describes a series of gigantic thrust-masses composed, in that district, of Permian, Triassic, Jurassic, and Cretaceous rocks that have travelled from east to west above the older crystalline rocks of the Central Alps, and have subsequently been downthrown along with the older rocks and suffered further deformation in the region of the Dolomites. The base of the series is composed of brecciated rock-material belonging to the floor over which the subjacent mass has passed and to the lower layers of the subjacent mass. The lower layers of each mass differ from place to place, as they were masses that had been already plicated in east and west direction, and in the course of the overthrust movements new plicational forms were superinduced both in north and south and in east and west directions. Similarly the cross-faults intersect, or coalesce with, the E.–W., E.N.E.–W.S.W., and W.N.W.–E.S.E. faults, and form fault-networks which completely isolate the adjacent areas in the crust. The chief Dolomite mountains, such as the Langkofl and Plattkofl Massive and Sella Massive, are areas of inthrow surrounded by faults, within which the higher thrust-slices have been preserved.

One of the geological maps shows four successive thrust-masses—(1) a basal thrust-mass mainly composed of the Permian Quartz Porphyry and Gröden Sandstones, the Lower Trias, and the *Calcareous facies* of Muschelkalk and Marmolata Limestone; (2) a thrust-mass comprising fragments of the older strata and widely extended exposures of the *porphyritic lavas and tufaceous and dolomite facies* of Middle Trias; (3) a thrust-mass belonging to the same facies as (2), but mainly composed of Schlern Dolomite, with varying thicknesses of the lavas and tuffs below it and of Upper Trias and younger horizons above it; (4) a thrust-mass mainly composed of Upper Triassic Dolomite associated with infolds of younger Mesozoic strata. The other geological map shows the detailed stratigraphy of the Langkofl and Plattkofl Massive. This mountain has been regarded as a 'Coral-Reef' of Middle Triassic age, but the supposed 'reef' peculiarities are

interpreted by Mrs. Gordon upon the basis of the overthrust structures typical of the whole area. The outstanding deformational feature of all the thrust-slices is the rapid variation in the thickness of the various horizons of strata. Other features are the brecciated or nodular structure of the rock-material in the crush-zones, passing into gneissose and schistose structure, and the close cleavage penetrating the rocks in intersecting directions. The outward dip of the strata noticeable in the chief mountain-massives is a dip participated in by the subjacent thrust-masses and associated with steep flexures towards leading faults of the later period of downthrowing and horizontal displacements. Mrs. Gordon interprets the leading strike in the district as a curve round the north, west, and south, and the transversal directions as N.N.W.–S.S.E., N.–S., and N.N.E.–S.S.W., the system being essentially an interference system produced in virtue of the coalescence of plicational effects during the interaction of north-south and east-west pressures.

REVIEWS.

I.—The Sub-Antarctic Islands of New Zealand.

Reports on the Geophysics, Geology, Zoology, and Botany of the Islands lying to the south of New Zealand. Edited by Professor Charles Chilton, M.A., D.Sc., F.L.S. Published by the Philosophical Institute of Canterbury. 2 vols. 4to; pp. xxxv, 848. Wellington, N.Z. London: Dulau & Co., 1909.

THE observations recorded in these two volumes are the results of an expedition made in November, 1907, with the co-operation of the New Zealand Government, to the more important islands that lie to the south of New Zealand.

The geology of Campbell Island and the Snares is described by Professor P. Marshall and Mr. R. Browne, and that of the Auckland, Bounty, and Antipodes Islands by Mr. Robert Speight and Mr. A. M. Finlayson.

In Campbell Island the oldest rock formation is a mass of gabbro. Somewhat larger areas are occupied by oceanic limestone, with foraminifera, occasional grains of glauconite, some flints, but no detritus: it is regarded as probably of Miocene age. The main mass of the island is formed of volcanic breccias and lavas (trachyte, phonolite, and basalt), the terraced features being due to the outcrop of nearly horizontal flows of lava, separated by less resistant scoria beds. Abundant evidence of glaciation was observed, but the formation of glaciers on the island is regarded as the result of a general cause of refrigeration and not as specially due to elevation. The absence of raised beaches and rock-shelves indicates that there has been no recent elevation, but it seems probable that a movement of depression is in progress.

The Auckland Islands exhibit evidence of "a moderately severe glaciation", and there are indications that it was probably more intense at an earlier date. Considerable elevation of the land must have occurred during those times, but the upheaval is not regarded as

having been a predominating factor in the glacial conditions. Nevertheless it is regarded as "reasonable that the Auckland Islands were at least 7000 feet high". The land now attains an elevation in places of more than 2000 feet, so that the uprise would have been 5000 feet or more, and would "go far to explain the connexion of New Zealand with a former antarctic continent". The main island of Auckland is mostly formed of basalt of middle or late Tertiary age. An older basic series, also conglomerate, which may represent an ancient river-bed, and trachytes, occupy smaller areas. Over more limited tracts there are exposures of granite and gabbro, the actual and relative ages of which are undetermined.

The rocky islands and islets of Snares and Bounty are formed of granite. Of the Bounty Islands it is remarked that "The rocks near sea-level are worn smooth not only by the action of the breakers, but also by the polishing action of the feet of the seals and millions of penguins and other sea birds, which make the island their breeding-place. The general rock-surface is as slippery as glass, and exceedingly difficult for man to travel over. Immense quantities of guano are deposited on the islands during the breeding season, but during winter storms it is swept off, with the exception of that which accumulates between the boulders".

Campbell Island and the Snares are much covered with peat, and there is a separate article on the soils and soil-formers, by Mr. B. C. Aston.

The main features of the islands are represented in a number of photographic illustrations and maps, and the rocks are illustrated by micro-sections. The entire work may be regarded as a substantial contribution to our knowledge of the natural history of these sub-Antarctic islands, with full references to the work of previous observers.

II.—Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1909. pp. iv, 92, with 5 text-illustrations. London: printed for H.M. Stationery Office, 1910. Price 1*s*. London, W.C.: T. Fisher Unwin.

THE important announcement is made by the Director, Dr. J. J. H. Teall, that the Survey of the South Wales Coal-field and that of the Derbyshire and Nottinghamshire Coal-field, on the 6-inch scale, have been completed, the work in the latter case having been connected with that carried out many years ago in the Yorkshire Coal-field by A. H. Green and colleagues. We learn also that the 6-inch field-work in Cornwall and Devon has been completed so far as at present contemplated. It is to be noted with regret that the name of the Director does not appear in the Summary; it was omitted also in the Summary for 1908. Such an omission is opposed to the prevalent notion that a man is responsible for the work he undertakes, and it is likely to give considerable trouble in the future to biographers and bibliographers. The policy of the Board of Education in omitting the names of the chief officers who contribute reports of the work of their departments to the General Report of the Board, is again a very inconvenient and unjustifiable piece of "red tape".

In Scotland the mapping of Ben Nevis has led to the conclusion that the volcanic rocks which form the higher part of the mountain are of Lower Old Red Sandstone age, and that they rest on Highland schists which are almost entirely concealed by bordering granites. The structure of this region forms the subject of a separate article by Mr. H. B. Maufe.

A short but important article is contributed by Mr. C. T. Clough on the stratigraphical relations between the Red Barren Measures and the Productive Coal-measures of Scotland. He states that there is no evidence of any break of importance between these divisions, and that consequently wherever the Upper Red Carboniferous strata occur, the Productive Measures may be expected beneath them. Mr. C. B. Crampton describes a Manganese deposit near Freswick, Caithness; Dr. W. Gibson gives an account of three borings in the Ingleton Coal-field; and Mr. John Pringle gives further particulars of a boring at Stowell, Somerset, that was carried through the Fullers Earth into the Sands beneath the Inferior Oolite. It is a remarkable fact that 25,000 gallons of water a day were obtained from the Fullers Earth Rock, and that the lower strata yielded no supply. Lists of fossils are given from the Inferior Oolite Series.

In the accounts of the progress of the field-work in the different districts of England, Wales, and Scotland there are records of many interesting observations on most of the geological formations from the Ordovician to the Lias, on Tertiary including the Bovey Beds, on Pleistocene and Recent deposits, as well as on the Highland schists, on certain supposed pre-Cambrian rocks (the Johnston Series) in Pembrokeshire, and on various igneous rocks. Analyses are given of clays from the Bovey Basin and from the Marland Clay Works, Torrington.

III.—Geology in the Field. The Jubilee Volume of the Geologists' Association (1858–1908). Edited by H. W. Monckton and R. S. Herries. Part IV. pp. 661–895, with 14 plates. London: Edward Stanford, 1910. Price 5*s.* net.

WITH the exception of a general and copious index which "will be ready shortly", the elaborate Jubilee Volume is now complete.

The present number opens with an article on "Northumberland and Durham", by Professor E. J. Garwood. After remarking on the scenery and tectonic features, the author gives a brief account of the Silurian, which is not known to include strata higher than the Wenlock Series. The unconformable Lower Old Red Sandstone with its andesitic lavas is next described, together with the intrusive rocks (granite and porphyrite) which indicate later phases of igneous activity. Upper Old Red Sandstone is doubtfully recognized in certain conglomerates at Windy Gyle, as the strata have been regarded by some geologists as basement Carboniferous. The various divisions of the Carboniferous and the palæontological horizons are duly described; and the author draws attention to the occurrence, apparently near the base of the

Yoredale Series, of *Posidonomya Becheri*, which is characteristic elsewhere of the Pendleside Group. The Permian beds are then dealt with, and it is noted that the Magnesian Limestone is succeeded conformably by Triassic red sandstones and marls—beds which, curiously enough, have been regarded as Keuper by some authorities. The important sills and dykes of post-Carboniferous date and the Glacial and newer deposits finally receive attention.

The second article is on "The Malvern and Abberley Hills, and the Ledbury District", by Professor T. T. Groom, who gives a summary of his detailed researches on the tectonic structure of the region, together with concise accounts of the Archæan and the fossiliferous Cambrian, Ordovician, and Silurian rocks. Special attention is given to the subdivisions of the Silurian, and a valuable list of fossils, showing the range of the species from the May Hill Sandstone to the Upper Ludlow, is appended.

"Shropshire" forms the subject of the third article, and is happily dealt with by Professor Lapworth. Brief accounts are given of the several types of pre-Cambrian rocks, the Rushton schists, the granitic and gneissose rocks, the Uriconian, and Longmyndian. It is remarked that the term Uriconian has been applied to certain disconnected groups of ashes and lavas, and in a table showing the apparent descending sequence of the lithological groups in Uriconian and Longmyndian the author has been led to place at the top the Linley volcanic series, equivalent to the Western Uriconian of Callaway, and at the base the Cardington volcanic series or Eastern Uriconian of Callaway. The intermediate groups of Western and Eastern Longmyndian are ranged under eight subdivisions. This classification, based on Professor Lapworth's detailed field-researches, will be of immense service to future workers. The Cambrian rocks are briefly described, and the various local divisions established by the author in the Ordovician system again give information of special importance. Then follow accounts of the Silurian divisions, and brief descriptions of Carboniferous and newer formations, of tectonic geology and physiography.

The fourth article, on "Charnwood Forest", is naturally written by Professor W. W. Watts, whose elucidation of the complex structure and of the nature of the buried mountain mass has been a great achievement. Preserved beneath a cover of Keuper Marl, the erosion of this newer deposit has revealed portions of what the author terms "the fossil Triassic landscape of Charnwood".

In the fifth article Mr. W. G. Fearnsides gives an account of the main features in the geology of "North and Central Wales". Rocks from pre-Cambrian to the Old Red Sandstone, sedimentary, volcanic, and intrusive, are duly described, attention being given to the prominent and characteristic fossils and to the method of formation of the strata. It is noted that the Old Red Sandstone is locally continuous in all respects with the Downtonian. The author then discusses the general structure of the area and the various great earth-movements that have taken place, and in a series of diagrammatic sections he illustrates his views on the more important stages in the building of Wales from the Uriconian era to the present day.

In the sixth article, by Dr. A. Strahan, "South Wales" is dealt with, mainly so far as the region has been visited by the Geologists' Association. Thus the oldest rocks described are the Silurian near Cardiff and in Gower. Attention is directed mainly to the Old Red Sandstone and Carboniferous rocks, the Trias and Lias, the Raised Beach and Caves of Gower, and the Glacial and post-Glacial deposits, concerning all of which is given a summary of the latest information, much of it acquired by the author during the progress of the geological survey. The intimate connexion between the Rhætic beds and underlying Keuper Marls, manifest from the stratigraphic and palæontological evidence noted by the author, is not, however, recognized by him, and his views differ from those of other writers in the Jubilee Volume (pp. 332, 491, and 863). In a final section on Physiography the author discusses the relations of the river-systems to the geological structure.

The seventh and final article, on "Cornwall, Devon, and West Somerset", is by Mr. W. A. E. Ussher, who has given accounts of a great series of formations from the most ancient rocks of the Lizard to the Pleistocene and Recent deposits. His table of strata and of igneous rocks, indeed, extends over more than two pages, and his task of summarizing the information on this varied series must have been an exceedingly difficult labour of love.

The igneous rocks and the China clay are first dealt with; then follows an account of the Lizard from the pen of Dr. J. S. Flett, who gives some of the results of his recent investigations on this complex group of mica-schists, quartzites, granulites, hornblende-schists, serpentine, gabbro, dolerite, and granite. The various schists of Start, Bolt, and Prawle are next described, and the author takes a "non-committal attitude" regarding their age. The results of recent work on the small areas of Ordovician and Silurian and on the Devonian and Carboniferous rocks form the most important portion of the author's article. As he intimates, a good deal remains to be done before the grouping and relationship of all the divisions of Devonian and Carboniferous are determined. While he hesitates to accept Hicks's view of the age of the Morte Slates, as the field-evidence does not favour the intercalation of Lower Devonian in the area where the Morte fossils were found, yet, as he remarks, "detailed mapping on the six-inch scale may vindicate Hicks's view."

The New Red Rocks and later deposits are described, some very briefly, but with special reference to recent researches.

IV.—Yorkshire Type Ammonites. Edited by S. S. Buckman, F.G.S. Parts I and II, pp. i–xvi, with 24 plates and descriptions. London: William Wesley and Son, 1909 and 1910. Price per part 3*s.* 3*d.* net.

THE object of the present work is to give descriptions and illustrations of the Jurassic Ammonites that were named by Young & Bird and by Martin Simpson. It is remarked that the type-specimens of which sketches without descriptions were published by John Phillips are lost; but the majority of the specimens described and illustrated by Young & Bird, and those described (but not figured) by Simpson,

are preserved in the Museum at Whitby. The Editor expects to deal with 150 or more species, and to complete his work in about sixteen parts, each containing from twelve to sixteen plates. The original descriptions of the fossils are reprinted, together with figures of the types admirably reproduced from photographs, mainly by Mr. J. W. Tutcher.

Of special importance is the illustration of the Simpson Collection. The specimens, as the editor remarks, had received "careful and discriminative studies", but without figures "it is almost impossible to obtain due knowledge of Lias Ammonites, and certainly dangerous to describe or name species as new". In identifying and figuring Simpson's species he has rendered a distinct service to palæontology. Simpson, although ready to add, where necessary, to the number of species, was averse to the multiplication of genera, and in this he will have the cordial sympathy of most geologists.

The editor gives definitions of biological, biogenetic, and other technical terms, also some notes on Ammonite development and on generic names. It is a defect that all the new names have not the suffix *ceras*, surely a convenience even for the palæo-biologist, who, as a rule, can alone find use for them; but the editor is by no means entirely responsible for this. He gives the latest of the generic Ammonite names, and a list of comparable species with references. This list is admittedly incomplete, but it might well have included all the names adopted by J. F. Blake.

Among the forms figured are *Ammonites mulgravius*, *A. exaratus*, *A. levisoni*, *A. lythensis*, and *A. lenticularis*; also one Nautilus, *N. subcarinatus*. To the ordinary geologist a Nautilus, however, is not an Ammonite. We trust that the editor will be well supported in his undertaking.

V.—Brief Notices.

1. Yorkshire Fossils.—Messrs. H. C. Drake & Thos. Sheppard have published in the Proceedings of the Yorkshire Geological Society, vol. xvii (1), 1909, a "Classified List of Organic Remains from the Rocks of the East Riding of Yorkshire", post-Glacial to Lias. This laborious piece of work aims at "placing in a convenient and compact form all the various and scattered records that have been published". No attempt has been made to revise the nomenclature, as it was felt that the older names would be more familiar to searchers. It is now easy to ascertain whether a given species has been previously recorded, and the reference to the authority and the place of publication have been indicated.

2. Department of Mines, Canada.—The Summary Report of the Geological Survey Branch of the Department of Mines, Canada, for 1909, issued 1910, contains much useful information on various subjects and localities. In his Report the Director, Mr. R. W. Brock, remarks that although the work undertaken by the Survey has been along strictly economic lines, the geologists are not engaged in prospecting. Thus "The Government geologist may recognize and direct attention to mineralized districts that afford promising ground